The Study of Microstructures and Stress-Strain Curves at Different Rolling Reductions for Al-3.8wt%Cu

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Abstract

In the present study, the microstructures features in case of rolled stripe were steadies for AL-3.8wt%Cu alloy in tensile tests at various temperatures as well as measured the stress-strain curves. The result obtained were used to deduce the amount of maximum stress and break stress and its corresponding strains in physical way from a gain in a deformation energy and microstructural studies from the features on optical micrograph.

Key words: microstructures, stress-strain, tensile test, Al-alloy.

دراسة التراكيب المجهرية ومنحنيات الاجهاد والانفعال عند الدرفلة المختلفة لـ Al-3.8wt%Cu

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الخلاصة

تم في هذا البحث دراسة التراكيب المجهرية للقطع المدرفلة لسبيكة (Al-3.8wt%Cu) من فحوصات الشد عند درجات حرارة مختلفة ، اضافة الى قياس منحنيات الاجهاد – الانفعال . تم استخدام النتائج التي حصلنا عليها لاستخراج كمية اقصى اجهاد وكذلك اجهاد القطع، اضافة الى ما يناظرها من الانفعالات بطريقة فيزيائية من الربح في طاقة التشوه ، وكذلك لدراسة التركيب المجهري بالطرق البصرية .

الكلمات المفتاحية : التراكيب المجهرية ، الأجهاد - الانفعال ، أختبار الشد ، سبائك الالمنيوم .

Introduction

In the conventional test of engineering tension, an engineering stress-strain curve is composed the load-elongation measurements made on the test piece of Aluminum alloys. The engineering stress,S, used in the stress-strain curve is the longitudinal stress in the tensile piece. It is represented as a division of the load , P , by the original cross – section of the specimen A_o ;

$$S= P/A_o \qquad (1)$$

The strain e, used for the engineering stress- strain curve is the average linear strain, which is represented as a division of elongation of the gauge length of the spicemen by its original length, L_O ;

$$e = \frac{\sigma}{L_O} = \frac{\Delta L}{L_O} = \frac{L - L_O}{L_O} \quad \dots\dots\dots\dots..(2)$$

The form and values of the stress-strain curve defends on the structure of a metal, be for hand history of plastic distortion, heat procession, and stress supposed during testing for the strain average temperature [1]. In this study Alloys were taken into consideration because in Al most elements only very set melt, produce the sedimentation easy ‘ also Al owns a very high stacking fault energy, undisturbed particles with other effects like the twin formation that happens in low stacking fault energy alloys, the important parameters in this study, a part from degree of rolling and recrystallization temperature, a retardation as well as an acceleration in recrystallization.

- Shear band formation during plane strain compression of alloy was studies [3].
- Alloy is very important for car and aeronautic industries [4].
- Al material is used for aircraft structures because it has lower weight and higher strength [5].
- High strain rate and uniaxial compression technique for slow rate deformation changes in mechanical response by increasing load or strain rate [6].
- The mechanical behavior of aluminum alloy changes after deformed in high and low strain rate [7].
- Shape memory alloys materials are smart and able to regain their original shape when their temperature increased to a certain value by heating [8,9].

Two types of symmetries take place for the crystal lattice.

- Martin site (high symmetry at a high temperature), the martensitic transformation [8, 10]
- The properties of pseudo flexibility and shape memory effect are making the shape memory alloys distinguishingly different from other materials [9, 11]
- The shape memory alloys conversion from phase with mono lattice structure (austenite) to several lattice structures (martensitic) with able to arrange. Themselves, that leads to no shape change observation [12].
- By applying pressures (mechanical loads), variants of shape memory alloys reorient into a single variant, which can cause inflexible strain [12].
- At a high temperature due to shape memory effect the flexible strain regained by martensitic phase returned to the austenite phase [12].
- Pseudo elasticity phenomenon can take place due to thermal and mechanical load application to the austenitic phase, directly this case leads to martensitic [12, 13].
- The paired systems of copper – zinc & copper-aluminum are two essential two Cu – based alloys that seem in the fields of the b phase [14].

- The triple system of these alloys regulate the transformation temperatures [15, 16]. The transformation temperatures are depended on the structure of alloys [15].
- Precision of (103 – 104) at more convenient than (5 K) for obtaining a reproducibility Cu – based alloys considerably less hysteresis than Ni Ti [16].
- The intension of improving the shape memory characteristics of alloys have been achieved in recent years , as well as to the increment of the commercial application (11, 14).

Experimental

Aluminum alloys encompass a wide range of chemical compositions & thus a wide range of harnesses. Many recovery & precipitation processes in aluminum alloys can occur at relatively low temperatures, such as (150 to 250 ˚C) (300 to 450 ˚F) [17].

a. Casting of Al- 3.8wt% Cu alloy :

A special furnace type (carbolite) was used for performing the casting of Al, Cu & other alloying elements . an alumina crucible has been used for mixing & handling the molten alloy. Initially the furnace was kept at (750 ˚C) well over the eutectic temperature of (548 ˚C) for Al-Cu system [18]. Consequently, other alloying elements conforming to the values given in Appendix (1) were added as follows:

Cu,Mg,Mn & Si respectively

The addition of the alloying elements were performed by injection of inert argon gas to prevent oxidation of the alloy & aided in increasing the molten state speed & also removed the dissolved gas. The injection of argon gas preformed preformed repeatedly inside furnace for the sake of molten operation & also homogenizing the molten alloy.

After well mixing, the molten alloy was charged directly into the graphite die already in position in the apparatus. The die was held at sufficiently high temperature (700 ˚C) to prevent the molten charge solidifying there by securing good flow of the molten charge in the die & also in obtaining a favorable casting conditions to eliminate cracks in the ingot.

By filling the graphite die in this way macrosegergation, which would otherwise occur due to freezing & remelting of the alloy, was avoided. Afterwards the molten alloy was allowed to cool quite naturally. The graghite die was parallelepiped shape with dimensions (50mm*50mm*300mm) & the cast ingot takes the shape & dimensions of the die. Slabs for the rolling processes were cut from the cast with a carborundum slitting – wheel, with dimensions of about (50*40*8) mm.

b. Stress-strain curve measurements:

Samples for tensile tests were prepared from an Al-Cu plate cold & hot rolled to a final thickness given in table (1) & table (2). The direction of specimen were cut from sheets parallel, (45°) & normal to the rolling direction. The samples were ensile tested in a computer controlled 30 ton force Schimedzu servopulserE20 machine with grips designed to give accurate axial alignment & freedom backlash , in addition to RT &(200°C) samples hot rolled & annealed at (400°C) for (1) hr . The strain gauge type extensometer model 5251 from flat specimen with 50mm gauge length was used. With increasing temperature the flow stress of alloy becomes increasingly sensitive to the deformation rate [19]. Therefore, the high temperature deformation should incloud this straim rate sensitivity [20, 21]. in the case of sheets, plates & odd sections it is not always possible to get a test of the standard shaped described above , so pieces are cut to rectangular section or whatever is most convenient. The stress & strain values shall be a nominal stress value obtained when load is divided by the sectional area of the specimen, & nominal strain value obtained & when elongation is divided by gauge length, respectively.

Results & Discussion

1- Variation in mechanical properties with the direction of a specimen:

The results of tensile testing in terms of maximum stress, young modulus, & strain are summarized in table (3). The maximum stress values showed very great orientation dependence & varied markedly, so as strain.

2- The microstructural of the alloy:

Microstructural studies have concentrated on the development of grain shape & size & possible identification of twin—slip system occur during deformation & recrystallization, these two aspects have to be covered here. Table (4) give the variation in grain size at various reductions between (17%) & (48%) for the cold rolled & colled rolled & annealed samples . no information cloud be obtained from hot rolled strip at (200°C) & same strips annealed at (400°C) as grain boundaries were indistinguishable .

3- Features on optical micrographs:

The microstructural features, table (5) in case of cold- rolled strips are:

a- The grain size decreases with an increasing rolling reduction, table (4), & ranges between 71 & 50.

b- The difference between cast & additional (for example 17% R.R.): dendrite disappear.

- Dendrite disappear
- Grain takes its shape with grain size 71 ,
- Elongation of grains along RD. but in 40% cold- rolled strip the grains are smaller with size 67 grains elongated along RD more than that in 17% R.R.

c- In case of 30% R.R. equiaxed grains pear-like shape, grain boundary exist.

d- In 48% R.R. the grain disrupted with no well-defined shape.

e- For annealed sample the grain b disappear boundary disappear where the grains grow on account of its grain boundary & the grain sizes ranges about 75.

In case of hot-rolled strips, the following observations were noted:

a- In 65% R.R. elongated grains of size (350*50) where observed with diffuse grain boundary.

b- In 70% R.R. the grain boundaries disappear as disruption took place.

Table (1): Cold – Rolled Strip of Al – 3.8wt% Cu alloy

Specimen No.	Original Thickness (mm)	Final Thickness (mm)	Rolling Reduction %
1	1.85	1.56	16
2	5.9	4.9	17
3	7.8	5.3	30
4	1.4	0.98	32
5	1.4	0.84	40
6	7.6	4.0	48

Table (2): Hot – Rolled Strip of Al – 3wt% Cu alloy at nominal Temperature 200°C for 1 hr.

Sample No.	Original Thickness (mm)	Final Thickness (mm)	Rolling Reduction %
1	1.7	0.13	93
2	0.9	0.11	88
3	1.0	0.13	87
4	1.35	0.18	87
5	1.4	0.2	86
6	1.0	0.15	85
7	1.5	0.22	85
8	1.49	0.30	80
9	1.4	0.33	78
10	1.5	0.31	78
11	1.75	0.39	78
12	1.2	0.27	78
13	1.3	0.31	76
14	1.3	0.33	75
15	1.2	0.36	70
21	6.55	4.7	28

Table (3): Stress – strain curve for Al- 3.8wt Cu alloy in the Rd

Cold rolled strips		Original Thickness (mm)		Hot – rolled at 200°C	Hot – rolled at 200°C Annealed at 400°C
R.R.%	Size (micron)	R.R.%	Size (micron)	No grain boundary ,grain merged	No grain boundary , grain merged
17	71	17	75		
30	67	30	75		
40	56	40	75		
48	50	48	75		

Table (4): Variation in grain size of Al- 3wt% Cu alloy

R.R. (%)	Condition	Young Modulus (GPA)	Max. Stress (kgf/mm^2)	Strain (%)
10	Cold rolled of annealed	16.5	17.75	-
38	Cold rolled of annealed	33	22.4	-
76	Rolled at 200°C	20	33.2	1.88
76	Rolled at 200°C of annealed	8	31.8	1.62
65	Rolled at 200°C of annealed	7	25.8	1.46
67	Rolled at 200°C of annealed	14	19.5	0.83
70	Rolled at 200°C of annealed	15	36.8	0.84

Table (5): Microstructure of Al – 3wt% Cu alloy, magnification by 102.4

Sample No.	Rolling Reduction %	Material	Comments
2	17	Annealed cold Rolled strips	Growth of grain on account of grain boundary
19	65	Annealed cold Rolled strips	Elongation 350×50 diffuse grain boundary
15	70	Annealed cold Rolled strips	Grains merged , no grain boundary
6	48	Cold - Rolled strips	Grain boundary exist,pear-like shape

Fourth alloying element effects on the mechanical and microstructure characteristics of copper – aluminum – nickel shape memory alloys [22]. This study promotes the shape memory characteristic and mechanical properties of copper –nickel – aluminum shape memory alloys by using further element in alloying procedure .the grain size and phase morphology were controlled by these additions element. The Co (1.14 wi %) was found that supplied the best general improvement in conditions of the transformation temperatures, flexibility, and regain the shape memory because of high presence of carbon [9]. The results of this study were compared with previous studies related to copper – aluminum – nickel shape memory alloy.

Conclusion

From the results illustrated in table (3) & figures (1 $\longrightarrow$ 7) for the stress- strain curves for Al-(3.8wt %) Cu alloy, we can deduce the following conclusion:

1. In the cold rolled & annealed strips, yong modules & maximum stress increases with an increasing in the rolling reductions.
2. Annealing decrease young modules, maximum stress & strain for the same rolling reductions.
3. Hot- rolling & annealing corresponding an increase in rolling reduction cause to an increase in yong modules & maximum stress but the strain was decreased .

Appendix (1)

Al-3.8wt% Cu alloy of our concern has grade designation

" ASTM 2014 " of chemical composition (*) :

3.8-5.0% Cu

0.5-1.2% Si

0.4-1.2% Mn

0.2-0.8% Mg

(*) Metal Handbook , 9th edition, ASM, vol.2 , (1979)

Appendix (1)

Tensile strength , specifications:

Model E20

Construction : Two Columns (hard chrome plated) actuator on the table .

± 20

Dynamic

Static ± 30

Max.load (ton f.)

Rigidity (for cross yoke table distance of 500 mm)

(mm/tf) 0.0065

Vertical shift-hydraulic

cross yoke

Fixing-hydraulic clamp

Testing space (mm) – Grip to Grip for ± 50 mm 250 – 1350

Distance stroke 450 -1750

The loading frame E series has two column & is equipped with an actuator on the table, the testing space is wide enough to accept various optional attachments such as jigs & devices for testing in different atmospheres. The high rigidity of the loading frame ensures high – fidelity transmission of load waves from the actuator to the specimen, because the load wave is hardly absorbed by the deformation of the frame. The Hydraulic system for vertical shift & clamping of the cross yoke ensures excellent ease of operation.

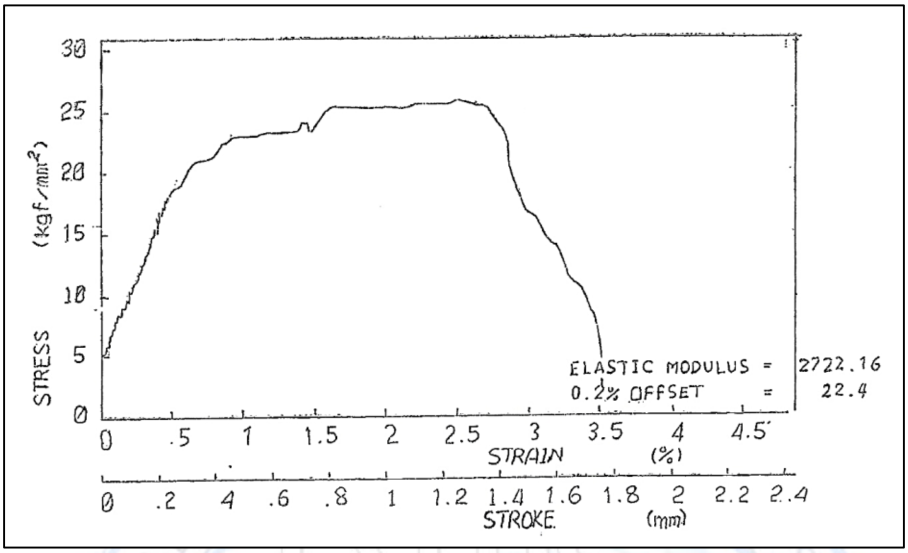

Figure (1) Stress – Strain , stroke curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 65 % rolled at 200° C / 1 hr and annealed at 400 ° C /1 hr

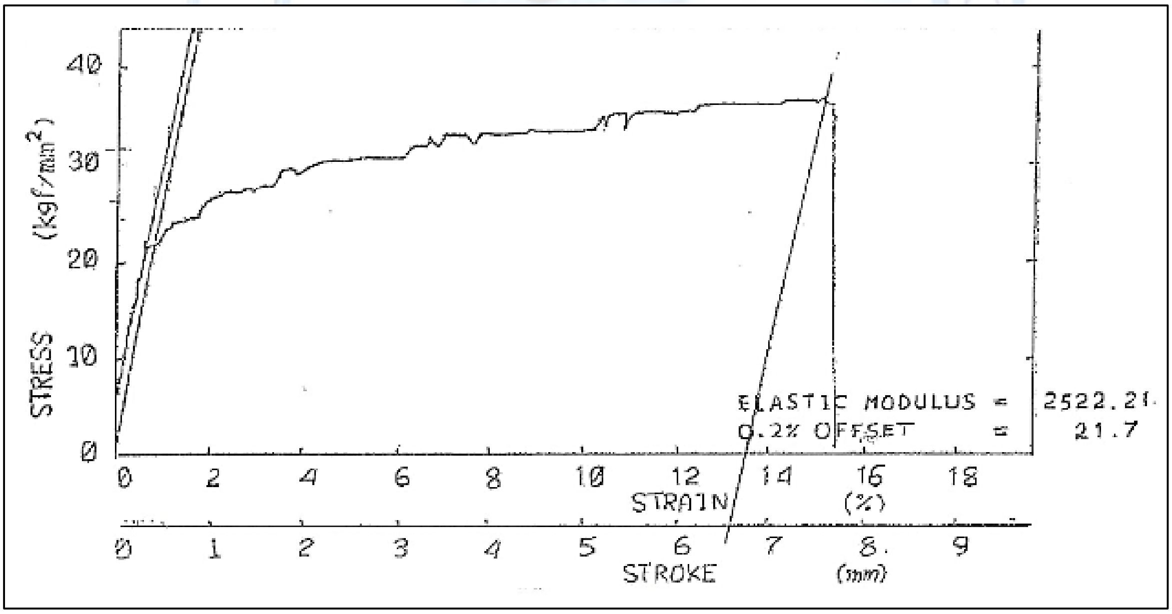

Figure (2) Stress – Strain, stroke curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 70 % rolled and annealed

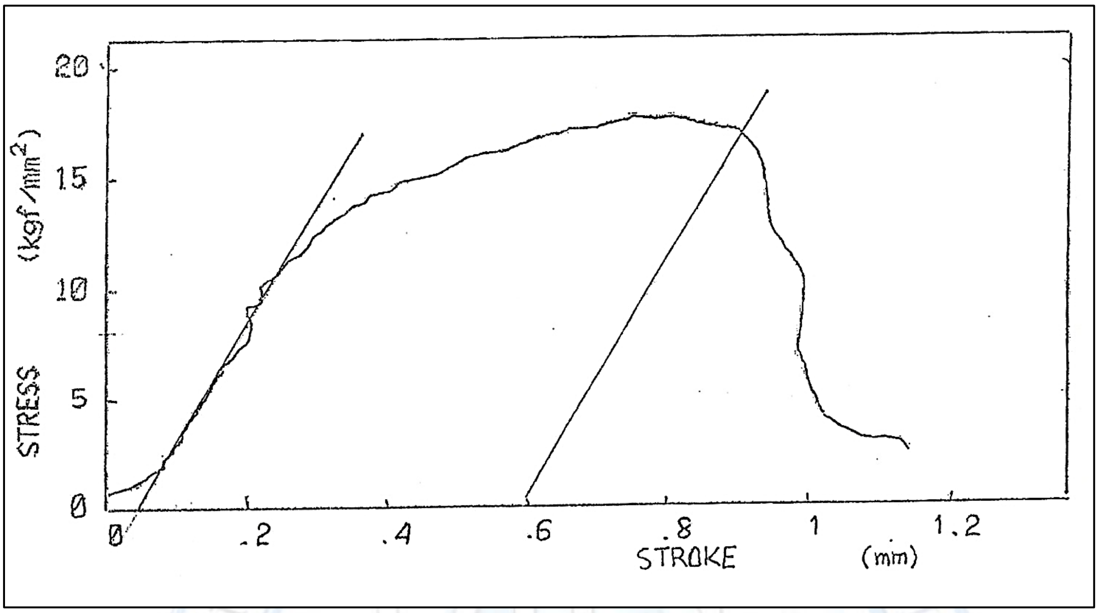

Figure (3) Stress – Strain curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 10 % cold - rolled and annealed at 400 ° C /1 hr

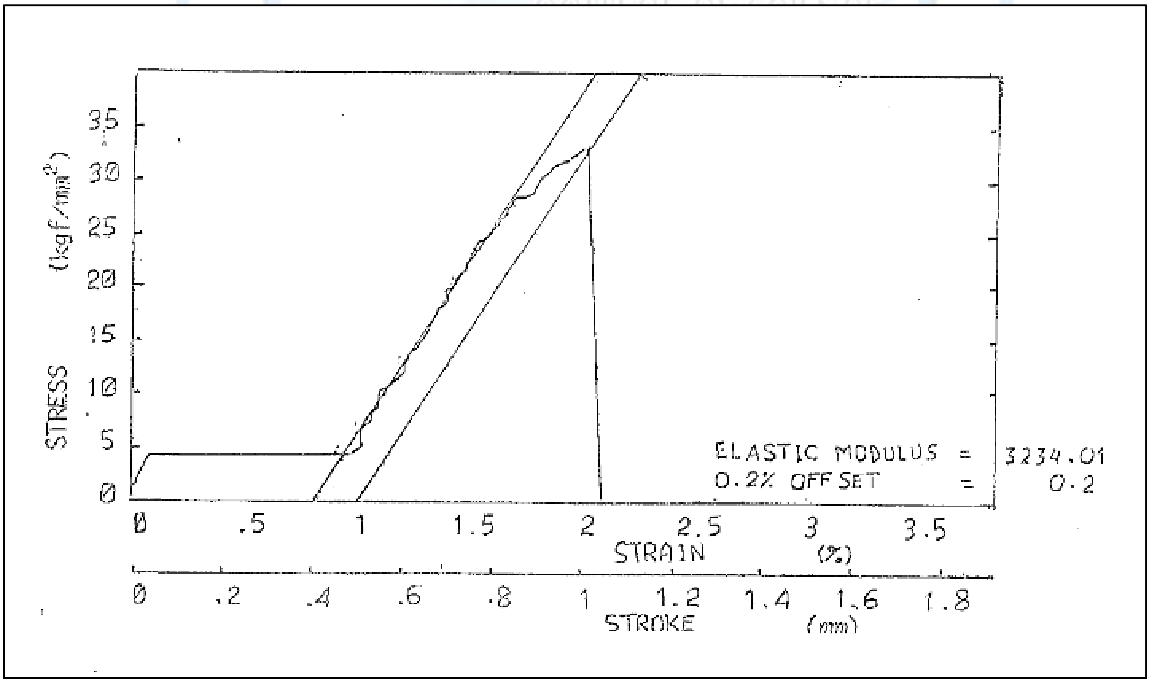

Figure (4) Stress – Strain curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 76 % rolled at 400 ° C /1 hr

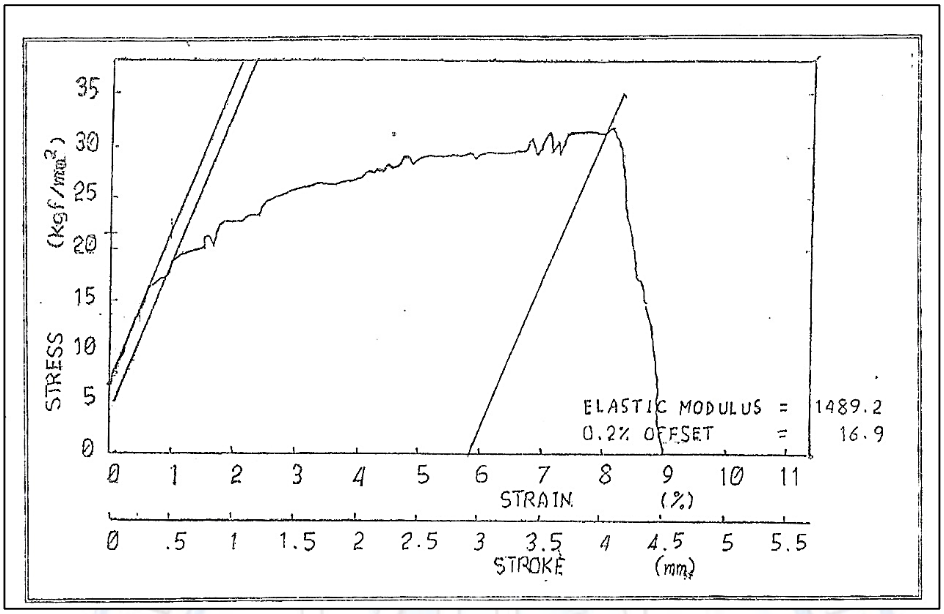

Figure (5) Stress – Strain curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 76 % rolled at 400 ° C /1 hr the annealed at 400 ° C /1 hr

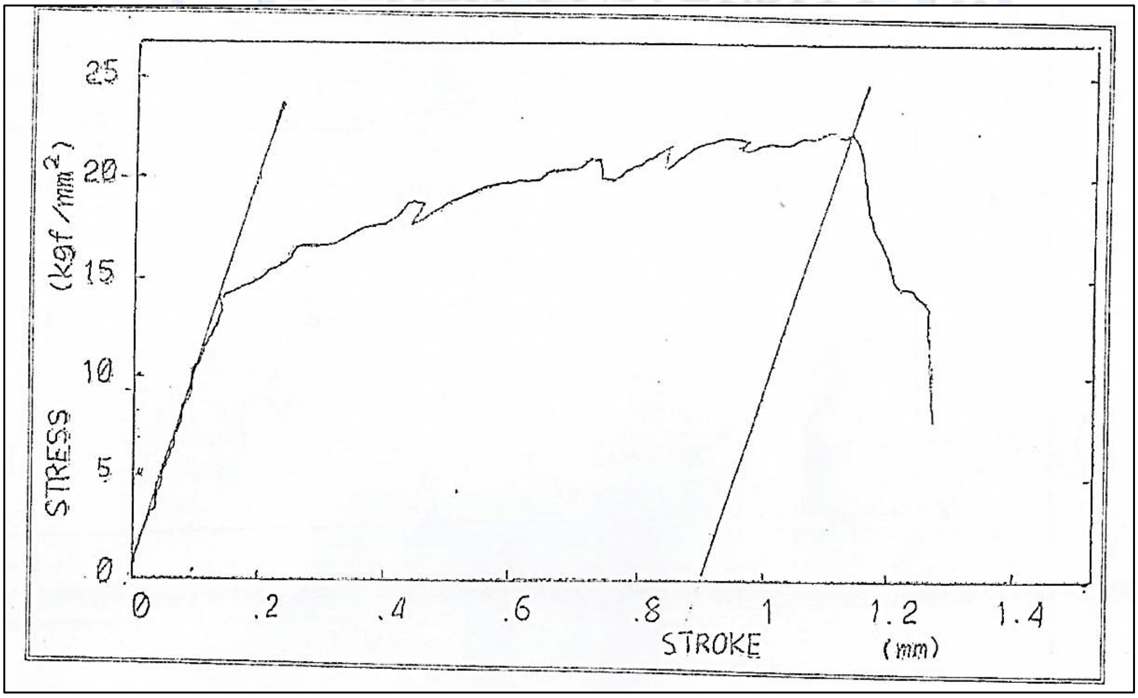

Figure (6) Stress – Strain curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 38 % cold – rolled then annealed at 400 ° C /1 hr

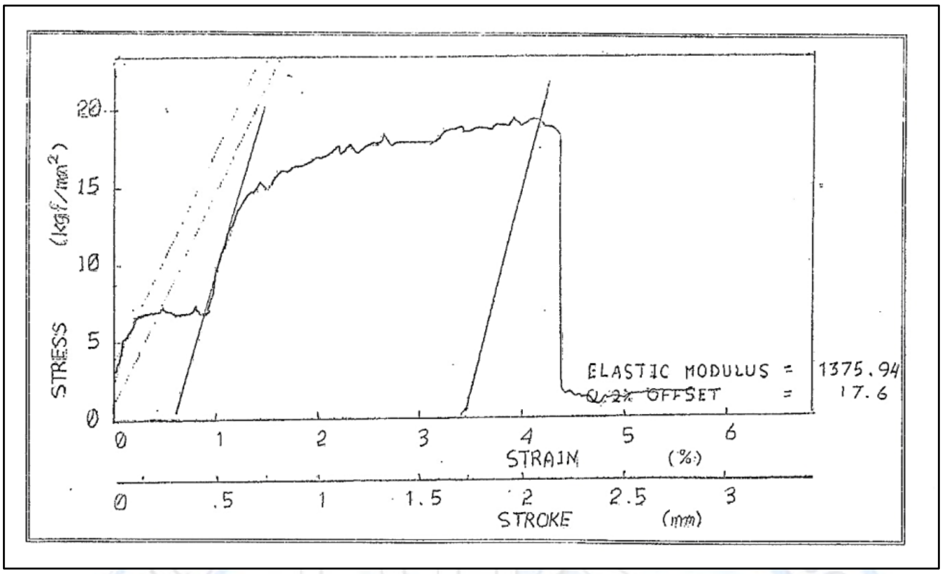

Figure (7) Stress – Strain curve for Al – 3.8 % Cu alloy in the RD for rolling reduction 67 % rolled at 200° C / 1 hr and annealed at 400 ° C /1 hr

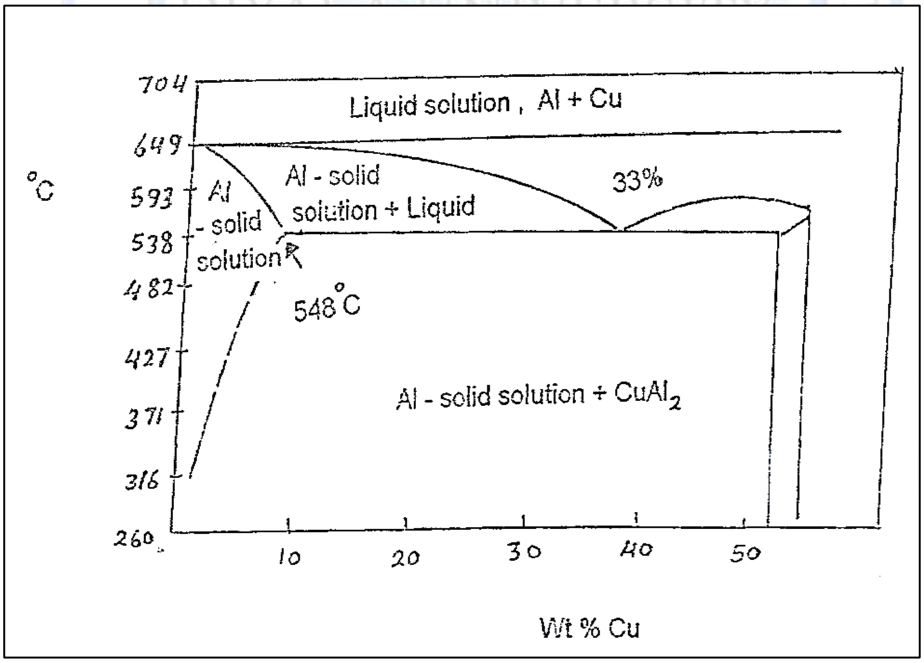

Fig (1) part of constitution diagram for Al - Cu alloy

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