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THE EFFECT OF STRAIN HARDENING AND ANNEALING TO HARDNESS AND MICROSTRUCTURE OF COPPER

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Keywords: annealing, rolling process, cold rolling, cod working, strain, copper.

ABSTRACT
The cold rolling process is to provide a plastic deformation to the metal by passing it between the high-pressure rollers to reduce the thickness of the metal (reduction) which will make the metal having a strain hardening phenomenon. Strain hardening effects that occur after having cold rolling can be eliminated by annealing process. To demonstrate the relationship of properties and structure of the material, cold-rolling research is carried out using copper plates. Copper specimens are made into 5 samples. Where the samples consist of annealing process treatment and rolling process. The result of the process of rolling and annealing treatment indicates that with the increase of strain in the copper after having the process of cold rolling, the higher also the value of the hardness of the copper. With the treatment of annealing process causes a decrease in copper hardness. As for the micro structure produced in the sample given the rolling process is showing the a flat and elongated grain, and for the sample without the treatment of rolling process indicates the shape of equaxial grain.

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INTRODUCTION

In the process of making a product, there is a process of forming on the material into the desired product. The process of forming the material can change the structure of materials so that material properties change. One example of material forming process is cold working (cold rolling).

Cold rolling process provides plastic deformation in metals by passing through the high pressure rollers to reduce the thickness of the metal (reduction) which will make the metal having strain hardening phenomenon, causing the material to get stronger and harder but become more ducting.

Strain hardening effects that occur after experiencing cold rolling can be eliminated by annealing process. The annealing process is done with the aim to make the hard metal become soft again. To make a change in properties that occur according to the desired product specifications, there needs to be a setting in the provision of deformation and the arrangement in the provision of heat treatment [1].

To know the mechanical properties of the material after experiencing cold rolling process then conducted testing such as hardness test, tensile test, impact test so that there is a magnitude that shows how the properties of the material such as hardness, ductility, modulus of elasticity, and so on. In addition, metallography testing can also be done to determine the relationship of the material microstructure with the mechanical properties.

To demonstrate the relationship of properties and structure of the material, cold rolling research is carried out using copper plates.

Copper is a type of metal that is widely used in electrical applications due to its high electrical conductivity. In addition to the high electrical conductivities, copper also has high thermal conductivities, good corrosion resistance, easy to set up, has high tenacity and toughness, and good recyclable properties. Copper has a FCC crystal structure (Face-Centered Cubic) [2].

MATERIAL AND METHOD

The specimen used is copper (Cu). before the cold working (rolling process), the copper is cut into 5 parts as the following image:

Cold working sample dimension, thickness T0 = 5,1 mm and width L0 = 23,3 mm.
For Copper Recrystallization Temperature. The Copper melting temperature = 1085°C = 1358 K. Where the recrystallization temperature = T melted (K) / 2 = 1358 K / 2 = 679 K = 406°C

The following is a table describing the sample that should be obtained by annealing and cold rolling [3].

Sample Code	Description
0	The annealing sample with a temperature of 410^0C and air cooled without rolling process.
1	Specimens without any treatment
2	Specimen of rolling process result once with width t_n = 5,1 mm and t_{n+1} =4,2 mm

3	Specimen of rolling process results twice, with width t_n = 4,2 mm and t_{n+1} = 3,1 mm
4	Specimen of rolling process results three times, with width t_n = 3,1 mm and t_{n+1} =2,1 mm
5	Specimen Sample 4 with annealing process treatment at 410^{0}C temperature and air cooled.

III. RESULTS AND DISCUSSION

1 Results of cold rolling process

From the results of cold rolling, the data obtained as follows:

Specimen samples	Initial thickness t_n (mm)	Final thickness t_{n+1} (mm)	Strain $\ln(t_n/t_{n+1})$	Strain values that have been experienced $\ln(5,1/t_{n+1})$	Description
2	5,1	4,2	0,19	0,19	One-time rolling
3	4,2	3,1	0,3	0,49	Rolling twice
4	3,1	2,1	0,39	0,88	Rolling three times

The strain that has been experienced can be calculated

$$\varepsilon = \ln \frac{t_n}{t_{n+1}}$$

where
ε = strain
tn = initial thickness
tn+1 = thickness after rolling process

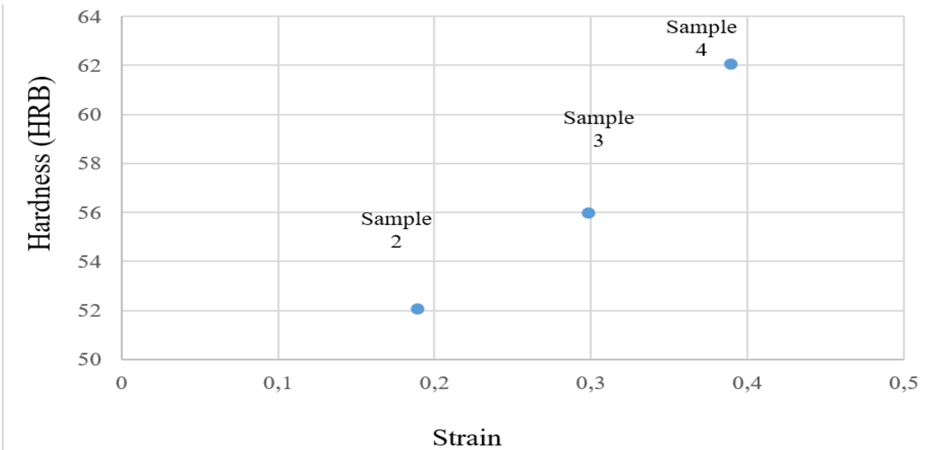
Thickness of specimen at the time of the rolling process suffered reduction while the width of the specimen remains 23.3 mm, this is caused because the direction of the rolling process force only occurs on the flat plane is not in the field, so only a thick part of the size changed.

2 Hardness Test

After the specimen is rolling and in annealing then the next is to conduct a hardness test [4]. The following is a hardness test result data.

Specimen Samples	Hardness (HRB)			Average (HRB)
0	18,2	20,7	23,4	20,8
1	48	47,3	47,6	47,7
2	51,6	53,2	52,9	52
3	54,5	57,6	55,7	55,9
4	61,6	62,1	61,7	62
5	33,9	32	28	31,3

From the data obtained the highest hardness is in specimen Sample 4 is the hardness value 62 HRB, followed by specimen Sample 3 and Sample 2 each with a hardness value of 55.9 HRB, and 52 HRB. While the lowest hardness value on sample 0 with 20.8 HRB value. The value of hardness in Samples 2, 3, and 4 is greater because in the specimen the specimen undergone a process of cold rolling in which during the process causes the material to have a hardness that is higher than the previous hardness, the increase in the value of hardness caused by the interaction between areas of strain that have been dislocated. When an object experiences strain strengthening, the specimen will have an exponential increase in the number of dislocations. As a result, the density of dislocation will become increasingly larger, because of the densities of the dislocation, then when a section is about to experience dislocations will be prevented by other dislocations. So the more amount of deformation given more and more new dislocation is formed so that the dislocation will be difficult to move. So the value of hardness will rise with increasing the rolling process. Whereas in samples 0 and 5 had a low hardness value because the specimen had an annealing process, in which the process density dislocation will be reduced and the effect of the strain hardening removed so that the value of specimen hardness dropped.
And the following is a graph showing the relationship of strains with hardness.

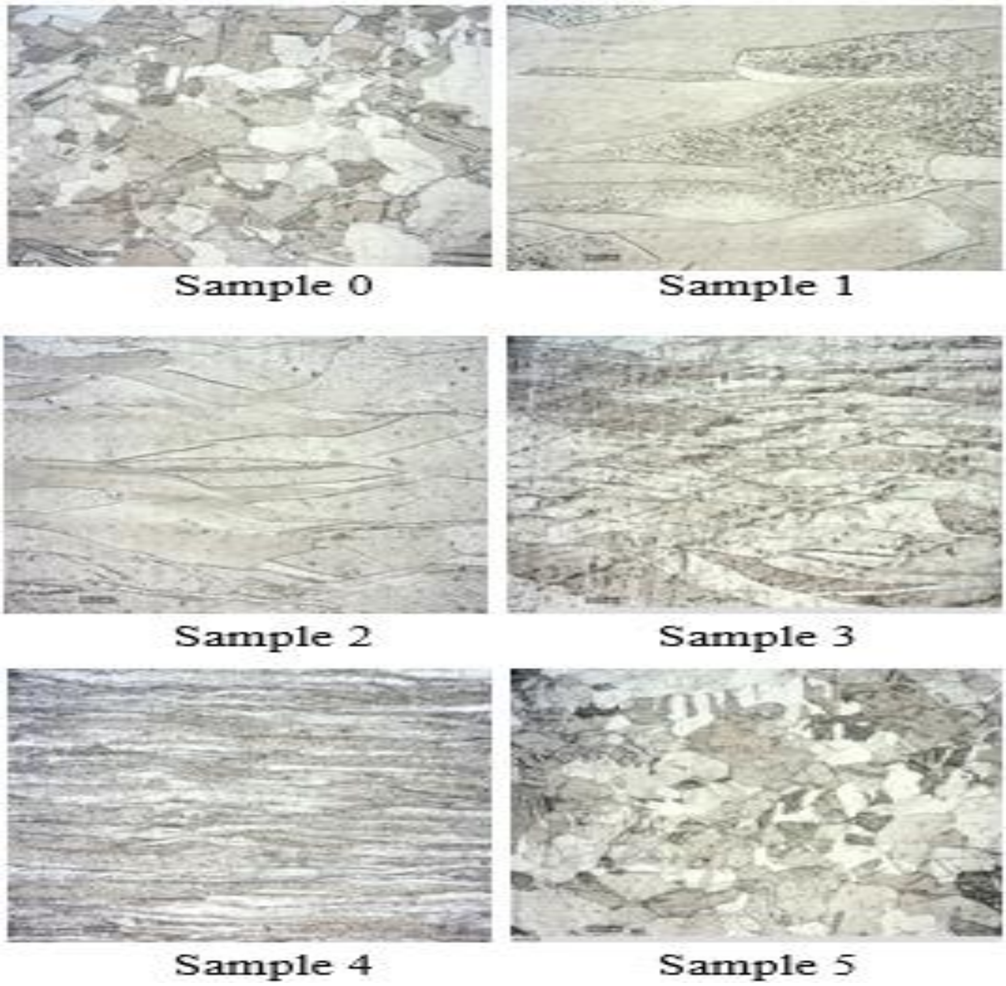


Graphic strain against hardness

From the above graph obtained that sample specimen 2, 3 and 4 undergo a process of rolling process so that the relation of strain with hardness is directly proportional if the strain rises then the hardness also rises. The highest hardness value is in specimen 4 samples with three times rolling with hardness value 62 HRB and strain of 0.39. This is because after the cold rolling, copper material is subjected to strain hardening due to the plastic deformation that occurs during rolling process, resulting in an exponential increase in the number of dislocations.

3 Metallography Test

The metallography test was conducted on 6 specimens of sample 0.1, 2, 3, 4, and sample 5. The following are micro structure images:



From the image of the micro structure above can be seen that for samples that undergo annealing process and samples that do not undergo the process of annealing differ, in the sample 0 and sample 5 that undergo the process of annealing grain form different from the sample 1 that does not undergo treatment, this is due to the sample 0 and 5 occur process of recrystallization phenomenon. Where the process of annealing copper is heated above the copper recrystallization, so it will cause the growth of new grains that have almost the same shape in each axis or equiaxial shapes. In sample 5 that underwent rolling and annealing process shows the change of copper grain form from the flattened to equiaxial again. In sample 0 and sample 5 there is twin annealing, where twin annealing due to the process of annealing and because copper has stacking fault low energy of 80 mJ M-2 [5].

While in specimen sample 2.3, and 4 which undergo the rolling process, produces

a more flatlow and longer grain shape. The shape is caused by a deformation that occurs due to cold rolling process so that the copper grains have a stretch (elongation) with the direction of strain parallel to the direction of the rolling. The greater the reduction at the time the curate causes the grain shape to be more flatless and elongated.

IV. CONCLUSION

1. with the increase of strain in the copper after experiencing the cold rolling process, the higher the value of the copper hardness.

2. The heat treatment of annealing above the recrystallization temperature leads to a decrease in copper hardness.

3. The more strain during the rolling process, the resulting grains will be more flatness and elongated, otherwise if not given the treatment of rolling process then the grain shape is almost identical in each axis or equiaxial.

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