Middle East Technical University

Department of Metallurgical and Material Engineering

Mete215 – Materials Processing Laboratory

Experiment 7: Mechanical Shaping of Materials

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ABSTRACT

Brass cartridge was put under 4 cold rolling process to reduce its thickness from 3.42 mm to 1.92 mm. During this process the change in hardness was observed and noted. An increase in the hardness was observed with every cold rolling step. The specimen that underwent 4 cold rolling process went under annealing at temperatures 200 ^{0}C, 300 ^{0}C, 400 ^{0}C, 500 ^{0}C degrees for 20 minutes. The change in the structure for each annealing was observed under a microscope and at higher temperatures the formation of grains were observed. At 500 ^{0}C the structure was roughly the same as the cartridge that did not undergo any process. The change in hardness was also observed in different annealing temperatures and it was conclude that as the temperature increased the hardness first increased but overall there was a decrease in hardness with The hardness of the sample that under went 4 cold rolling process being 141 VHN and the sample at 500 ^{0}C annealing being with hardness 60.7 VHN.

INTRODUCTION

Metals in the industry are obtained by melting them with the use of furnaces which are then poured to molds. It is known that metals are needed in variety of shapes and sizes. To get a desired shape it must go under some processes termed as deformation processes. There are several ways for the deformation process to occur such as rolling, forging, extrusion drawing and such (University of Cambridge, n.d). With the consideration of some factors the process can happen in a hot or cold way. Mostly when there is going to be large material movement or sometimes called as bulk deformation, hot deformation process is used like rolling or forging (Campbell, 2008). Therefore, it can be said that when the section size of the material that is going to be worked on is big than hot deformation is used and when the section size gets smaller the cold deformation process is to be used.

Hot working is when the process is done above half the amount of melting temperature of the material. In this process, recrystallization occurs that results in the formation of grains that are stress free. For example, in a hot rolling process the deformation happens in in a relatively short zone and in the case that the process prolongs the steps of deformation, recrystallization and grain growth occurs which result in finer grains (Campbell, 2008). From this it can be said that a material that underwent a deformation process is more reliable than that of the material where it just solidified after being cast.

Cold working is done when there is less material movement in the deformation process and more homogeneity is desired like the production of thin sheet metals. It is generally done under room temperatures. Materials like steel after cold rolling are hardened as the result of the dislocations impeding each others movement as a result a process called annealing is done to soften the material (Tohru luchi, 2010). The annealing is where the material is put to furnaces and the elongated grains due to cold processing are recrystallized as well as the homogeneity is achieved. At the end of the cold rolling and annealing process a material that is reduced but has mostly the same structure is achieved.

In the above discussion examples of rolling was given as it is a highly popular deformation process (The library of Manufacturing, n.d). However, there is a limit to the amount of reduction that is possible due to the forces involved in the process. Since this is the case there may arise a need to the process more than one time to achieve the desired thickness.

The amount of reduction is calculated by;

$e = (l_1-l_2)/l_1 * 100$ where l_1 is the thickness before the reduction and l_2 is the thickness after the reduction.

Engineering strain is the amount of deformation in the direction that the force is applied (NDT resource center, n.d). It can be shown with the equation;

Strain = Elongation / Original length

In a similar way true strain is calculated with the equation;

$\varepsilon = \ln (l_2 / l_1)$ where the parameters are the same as in the calculation of amount of reduction.

EXPERIMENTAL

Materials and equipment that were used;

- Cartridge brass
- Hardness tester
- Light microscope
- Furnace
- Vernier calipers
- Cutting machine
- Rolling mill

Procedure

The experiment started with the initial testing of the hardness and the thickness of the cartridge brass specimen. The thickness was measured by a hardness tester and Vernier caliper was used to measure the thickness of the material. It is important to note that more than 1 measurement in different parts of the material were done during the hardness test as to get a more accurate result. Then the specimen was put into the rolling mill for the reduction of its thickness where after the thickness and hardness test were done again. This process was done a total of 4 times. Each time the thickness and hardness were noted and the specimen was reduced more. In the end of this cold rolling process the specimen was cut into 4 pieces with the use of a cutting machine. The four specimens were each put in a furnace for 20 minutes that had different temperatures. Namely, 200 ^{0}C ,300 ^{0}C ,400 ^{0}C ,500 ^{0}C. This was the annealing process for the cold rolled specimen. To see the change in structures it was desired to put the four samples under a microscope. To be able to see the structure under a microscope a number of operations had to be done. These were the grinding, polishing and etching steps. When these were done to our specimen the structure was observed under the microscope. Finally, once again the hardness of the specimen was measured and noted.

RESULT

	Initial (VHN)	First Pass (VHN)	Second Pass (VHN)	Third Pass (VHN)	Fourth Pass (VHN)
Brass	66.7	93.3	118	132	143
	78.8	98.4	115	130	136
	69	97.9	116	133	144
Average (VHN)	71.5	96.5	116	132	141

Table 1. The hardness of the specimen after each cold rolling process. (Vickers Hardness were found by multiplying Brinnel hardness with 0.95 to convert)

	Fourth pass (VHN)	200 ^{0}C (VHN)	300 ^{0}C (VHN)	400 ^{0}C (VHN)	500 ^{0}C (VHN)
Brass	143	149	91.4	67.6	61.9
	136	150	129	76.0	64.0
	144	150	152	85.1	56.2
Average(VHN)	141	150	124	76.2	60.7

Table 2. The hardness of the specimen after annealing process at different temperatures. (Vickers Hardness were found by multiplying Brinnel hardness with 0.95 to convert)

Table 1 is the data that has been noted every time the hardness test is done on the specimen that went through cold rolling process. Table 2 also shows the data of hardness of the specimen that has been noted after the annealing process was completed at different temperatures.

	Initial	First Pass	Second Pass	Third Pass	Fourth Pass
Thickness (mm)	3.42	3.18	2.77	2.30	1.92

Table 3. The measured thickness of the specimen

Table 3 shows the data of the thickness of the specimen after each cold rolling process.

The true strain of the material is measured by the equation;

$$\varepsilon = \ln (l_2 / l_1)$$

where l_1 is the thickness before the reduction and l_2 is the thickness after the reduction. The true strain after each cold rolling is as follows;

$\varepsilon_1 = \ln (3.18 / 3.42) = -0.073$
$\varepsilon_2 = \ln (2.77 / 3.18) = -0.138$
$\varepsilon_3 = \ln (2.30 / 2.77) = -0.186$
$\varepsilon_4 = \ln (1.92 / 2.30) = -0.181$

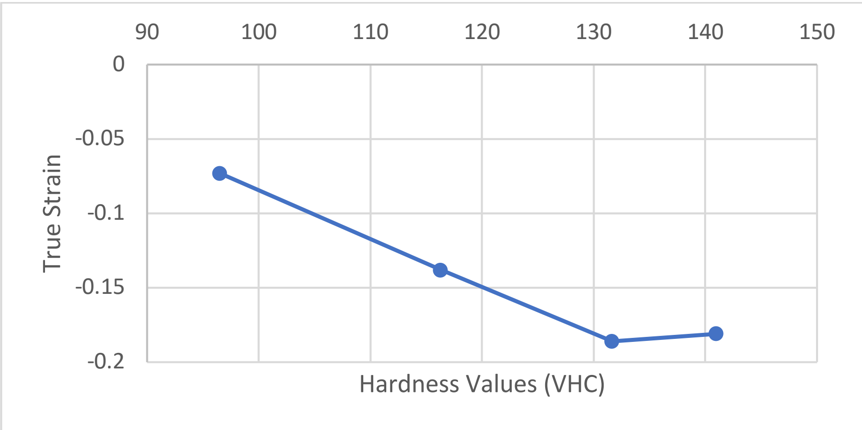

Figure 1. the hardness vs strain graph

Figure 1 depicts the change in true strain with hardness.

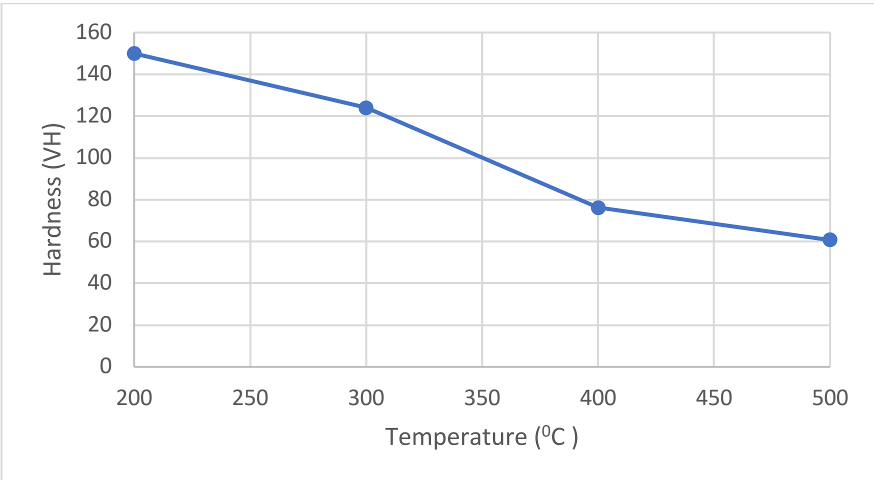

Figure 2. temperature vs Hardness graph

In figure 2 the change in hardness can be observed as temperature changes.

DISCUSSION

Table 1 shows the data of the hardness test after each cold rolling process. It can be seen that with each cold rolling done the hardness of the specimen increased. This is because with each deformation the dislocations begin impeding each other movement which then results in the increase of the hardness. Table 3 shows the reduction of the thickness of the specimen. It can be said that the thickness decreases after every time the specimen goes into the rolling machine. From these values of reduction, the amount of true strain was calculated and shown in figure 1. It can be concluded that overall as the hardness increases the true strain increases. The annealing process is done by putting the specimen inside furnaces. In this experiment the annealing was done in four different temperatures and the structure was observed under the microscope. The specimen that did not undergo any annealing was also observed.

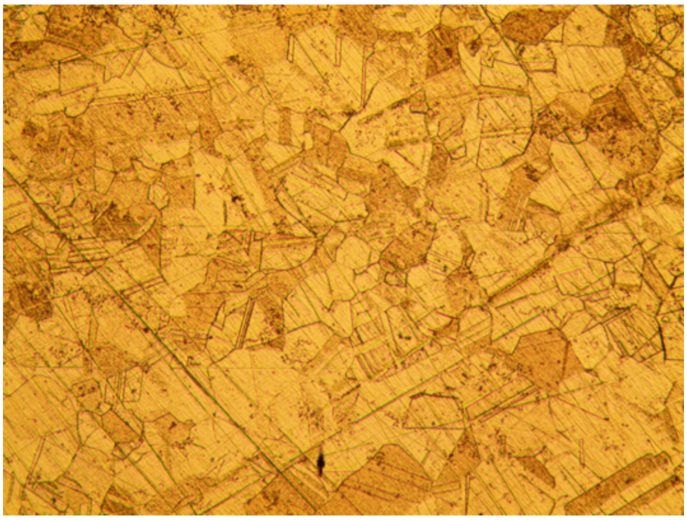

Figure 3. The microstructure of the specimen that did not go through any process

For the specimen that was not annealed and did not undergo any cold rolling process which can be seen in figure 3, the dimensions of the grains are roughly the same.

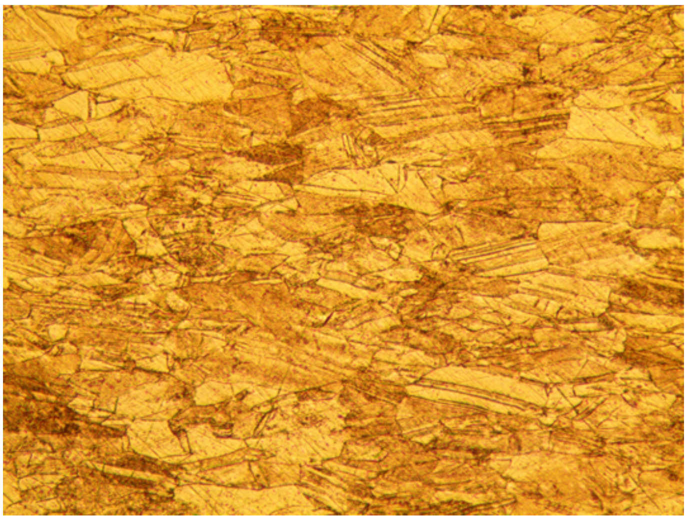

Figure 4. The microstructure of the specimen that went through cold rolling process

For the specimen that went through cold processing but not annealing as the figure 4 illustrates, the grains can be seen as elongated in the direction of cold rolling.

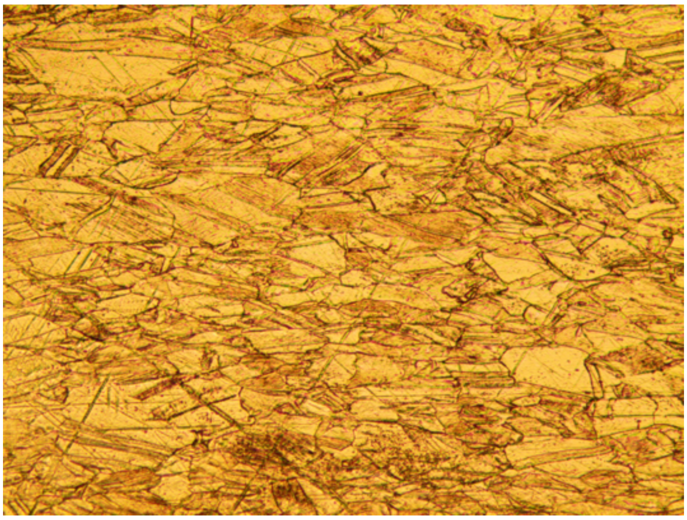

Figure 5. The microstructure of the specimen that went through annealing process at 200 ^{0}C.

For the specimen that went annealing process at 200 ^{0}C, from the figure 5, not that much of a change could be seen as this temperature is not enough for fast recrystallization. From table 2 it can be seen that this is the hardest specimen as the grains are in optimal energy condition.

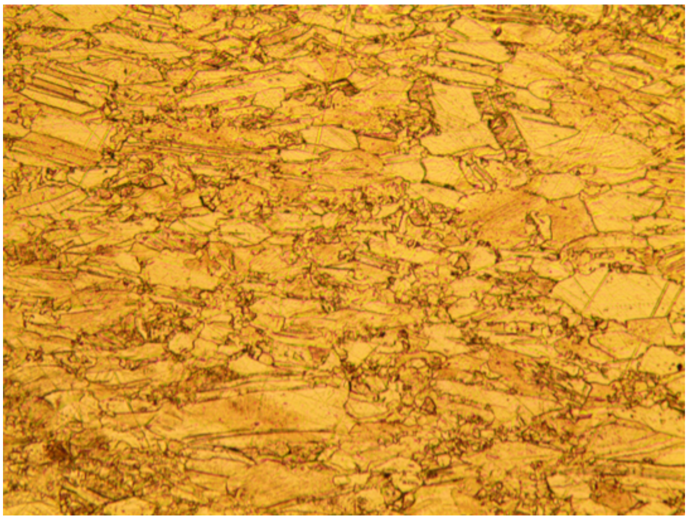

Figure 6. The microstructure of the specimen that went through annealing process at 300 ^{0}C.

In figure 6, the specimen that went annealing process at 300 ^{0}C is shown. From this, the little grains that started to be formed by the recrystallization could be observed. This can be considered as the start of the recrystallization.

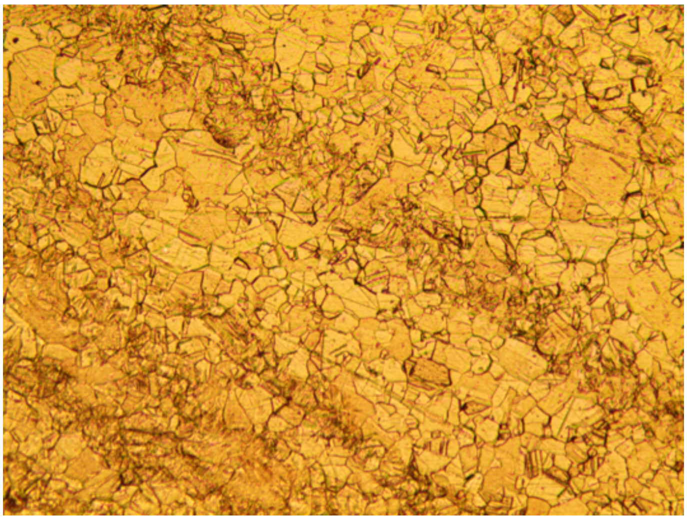

Figure 7. The microstructure of the specimen that went through annealing process at 400 ^{0}C.

For the specimen that went annealing process at 400 ^{0}C as can be seen from figure 7, much more recrystallized grains can be seen. Therefore, it can be said that dislocation density decreased and the hardness is also is expected to decrease which is the case as from table 2 the drop of the hardness is clearly seen.

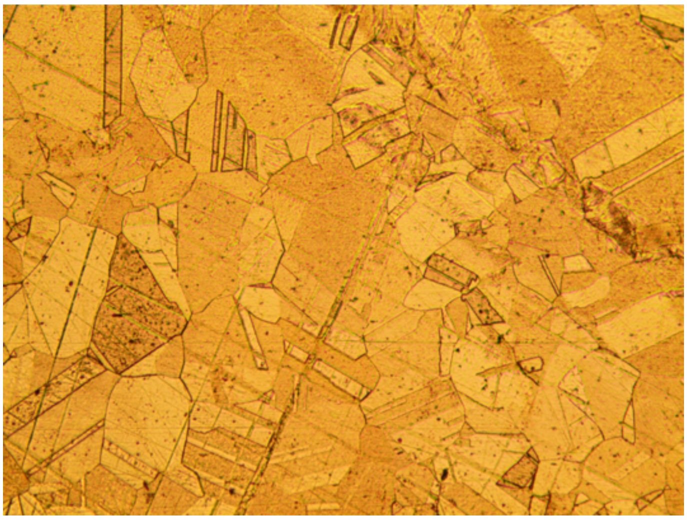

Figure 8. The microstructure of the specimen that went through annealing process at 500 ^{0}C

Figure 8 shows specimen that went annealing process at 500 ^{0}C. The growth of newly formed grains is seen and the structure is similar to that of the initial structure that did not undergo any cold rolling or annealing process. The hardness once again dropped at this temperature and it is quite similar to that of the initial specimens.

CONCLUSION

Shaping of materials is a very important concept for example, in the industry the metals are mass produced in certain shapes but according to place it is going to be used the shape must be changed. This is done with processes called deformation processes. The process can happen either hot or cold. In this experiment the cold rolling and annealing processes were done and observed. It was seen that as cold rolling was done the hardness of the material increased and so did the strain of the material. This is something that may not be wanted as it will be more brittle with the increased so to soften it annealing is needed to be done. With the combination of these two processes a brass cartridge of certain thickness became less thick but the structure did not change. Therefore, a change of shape was obtained without deforming the material.

REFERENCES

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APPENDIX

Conversion from Brinnel hardness to Vickers hardness;

VHN = 0.95 * BHN