Annealing And Recrystallization Experiment

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Section: E45 -2B

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Date:

Quarter: Fall

Abstract:

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A common method of changing the mechanical properties of a metal is by annealing, a common procedure of deformation processing. Six brass samples, each annealed at a different temperature, were first investigated under a microscope, then hardness tested, and finally, tensile tested. We discovered that each mechanical property had a changing relationship with temperature, which confirms that deformation processing rearranges the material's mechanical properties. It was noted that the Ultimate Tensile Strength and Yield Strength each decreased with a rise in annealing temperature. The results found the homologous recrystallization temperature to be 0.501 T_m, which is relatively close to the expected value of 0.3 T_m - .5 T_m.

Introduction:

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Deformation processing is a useful method to obtain desired dimensions and precise properties of a material. The creation and motion of dislocations is directly involved with the deformation in a material. An increase in the density of dislocations is called strain hardening, which strengthens the material since the movement of the dislocations is restricted. An increased dislocation density may cause the material to become extremely brittle, leaving the material with a low elongation percentage (DUCTILITY?),. A technique used to reduce this dislocation density is to anneal the material. The time and temperature of the anneal depends on the material, the desired final properties, and the degree of prior cold work of the material. When a material is annealed there are three separate phases that the material goes through. The first phase, recovery, is the initial state of annealing in which atomic mobility is sufficient to allow some softening of the material without a significant microstructural change. The second phase, recrystallization, is the nucleation and growth of a new stress-free microstructure from a cold-worked microstructure. During this phase, there is a drop in hardness in the material, and the dislocations within the microstructure pass out of the material. The final phase, grain growth, is the increase in average grain size of a polycrystalline microstructure due to solid-state diffusion. These definitions are as defined by James F. Shackelford.

In this experiment, the effects of annealing on various microstructural and mechanical properties are investigated with the use of various materials.

Procedure:

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Beginning this lab, various microstructures were looked at under a microscope to understand the properties that this lab deals with. Then the Rockwell hardness test was done with six brass samples which were previously annealed at various temperatures. This “is WAS done on the shoulder sections of the samples. After completing five trials of each, the tensile tests were done. Each specimen was loaded into the Instron 4204 machine and tensile tested to failure. All initial and final dimensions were recorded and Young’s Modulus, Yield Strength, UTS, and Elongation % were calculated. These were graphed versus temperature.

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Results:

In figure one, a best fit line for percent elongation would show a relatively increasing linear relationship with temperature. In figure two, hardness would remain relatively constant until the recrystallization temperature is reached, and then hardness has a decreasing linear relationship with temperature. This is assuming the hardness of the 775 °C would be lower if annealed for one hour instead of six. In figures three and four, yield strength and tensile strength also show a decreasing linear relationship with temperature, although the decrease in yield strength is significantly more than the decrease in tensile strength. Finally, figure five shows a plot of Young's Modulus versus temperature, but it is not possible to determine any sort of relationship from this plot due to the extremely large variations in data. These variations are largely due to the error associated with the Instron machine. The arms may be able to move without that movement being taken into account by the computer. Error in measuring the initial and final dimensions were relevant due to the human error in using the calipers. A constant measure of the instantaneous cross sectional area was not taken. Also, measuring the harder samples on the HRB scale should be measured on the HRF scale. The HRF hardnesses are 73.72, and 76.7 for samples one and two, respectfully.

GOOD.

USE WRITTEN OUT NUMERICALLY MAKES THEM STANDOUT MORE FROM THE TEXT,

HRB

RESPECTIVELY?

HRB WILL GIVE A LOWER NUMERICAL HARDNESS FOR THE SAME MATERIAL WHEN COMPARED TO HRF.

The brass samples delt with are 70/30 copper to zinc ratio. The recrystallization temperature observed are ~598 K and a known melting for this composition of ~1193 K. The recrystallization temperature divided by the melting temperature gives a .501 ratio, which is extremely close to the expected value of 1/3 - 1/2 of the melting temperature. Given the error in these numbers, the results support previous experiments.

Figures six through nine show the transformation process of the cold worked material. Figure six shows the structure as received. The grains are disorganized, and have different sizes. In figure seven, recrystallization has begun and the grains appear to be equally sized, and organized. In figure eight, recrystallization is complete and grain growth has begun. In figure nine, the grain growth procedure is complete,and now the material is not as hard as it was when the process started. Most of the softening is done before the grain growth stage begins. Figures six through nine have a magnification of ~75X. WHICH ANNEALING TEMPERATURES CORRESPOND TO WHICH FIGURES?

The amount of cold work for a specimen is given by the final cross sectional area subtracted from the original cross sectional area, then the difference divided by the original area. For samples one and four, the % cold worked was 69% and 70%, respectively.

Table 1:

Initial Specimen Dimensions

Specimen Number	Length (mm)	Width (mm)	Thickness (mm)	Area (mm**2)
1	25.4	6.1	1.5	9.15
4	25.4	6.1	1.4	8.54

Final Specimen Dimensions

Specimen Number	Length (mm)	Width (mm)	Thickness (mm)	Area (mm**2)
1	34.324	4.05	0.7	2.835
4	45.505	3.6	0.7	2.52

Table 2:

25°C

Specimen Number	Annealing Temperature, C	Annealing Time, hours	Young's Modulus (GPa)	Yield Strength (MPa)	UTS (MPa)	Elongation (%)	Rockwell Hardnes (F scale)
1	175	1	12.7	444	480	35.1	100.22
2	275	1	8.625	400	433	36.4	101.9
3	375	1	12.83	290	421.8	45.83	95.6
4	475	1	7	140	410	77.2	67.76
5	575	1	18	123	326	83.4	58.8
6	775	6	2.14	48	261.8	82.64	30.82

Figure 1:

DEPENDENT AND INDEPENDENT VARIABLE AXES ARE SWITCHED

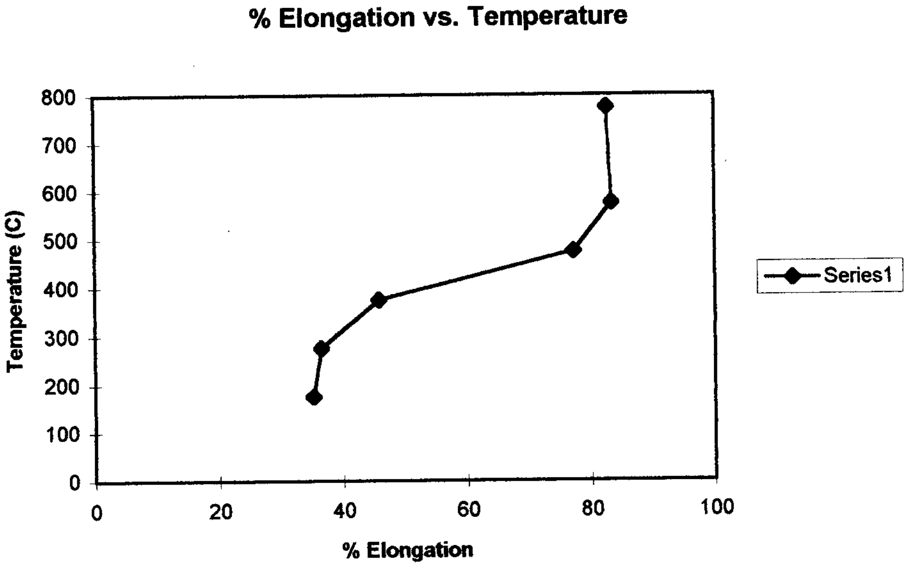

Figure 1 displays the % elongation versus the Temperature in degrees Celsius.

Figure 2:

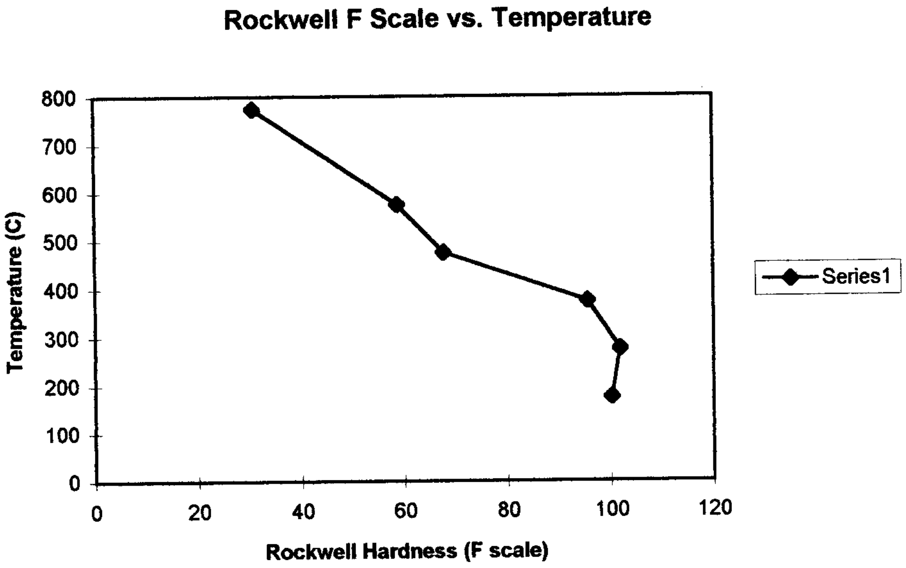

Figure 2 displays the Rockwell F scale versus temperature in degrees Celsius.

Figure 3:

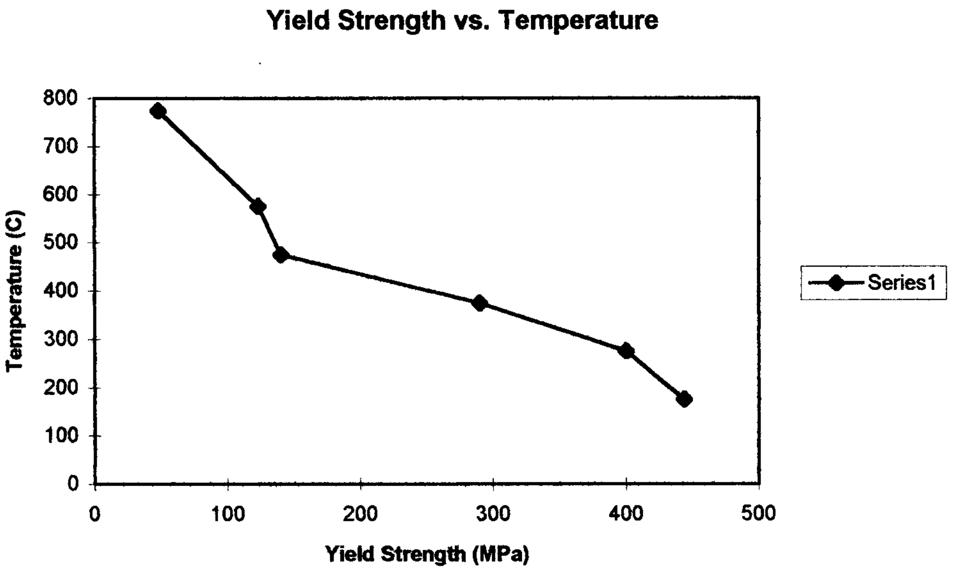

Figure 3 displays the yield strength of brass versus the temperature.

Figure 4:

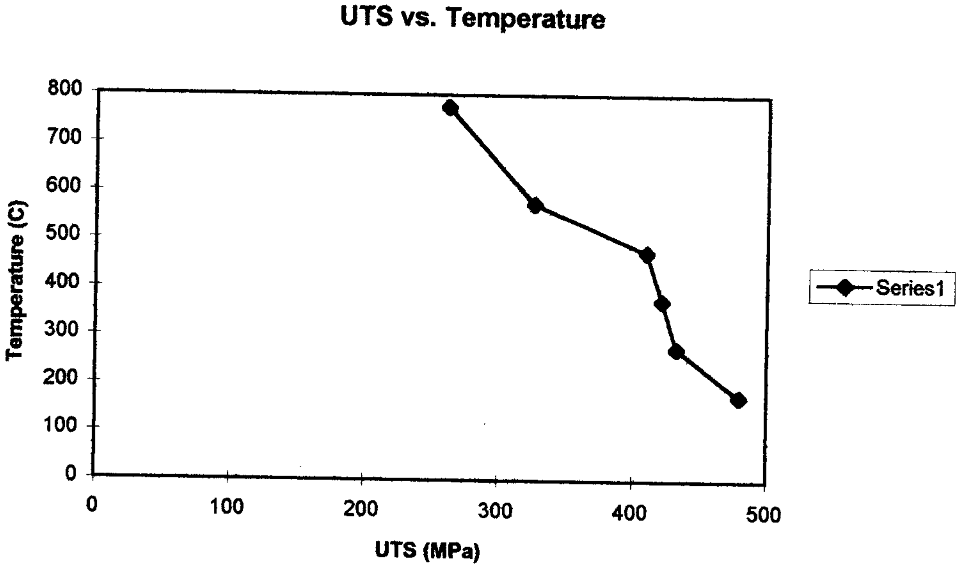

Figure 4 displays the UTS versus the annealing temperature of brass.

Figure 5:

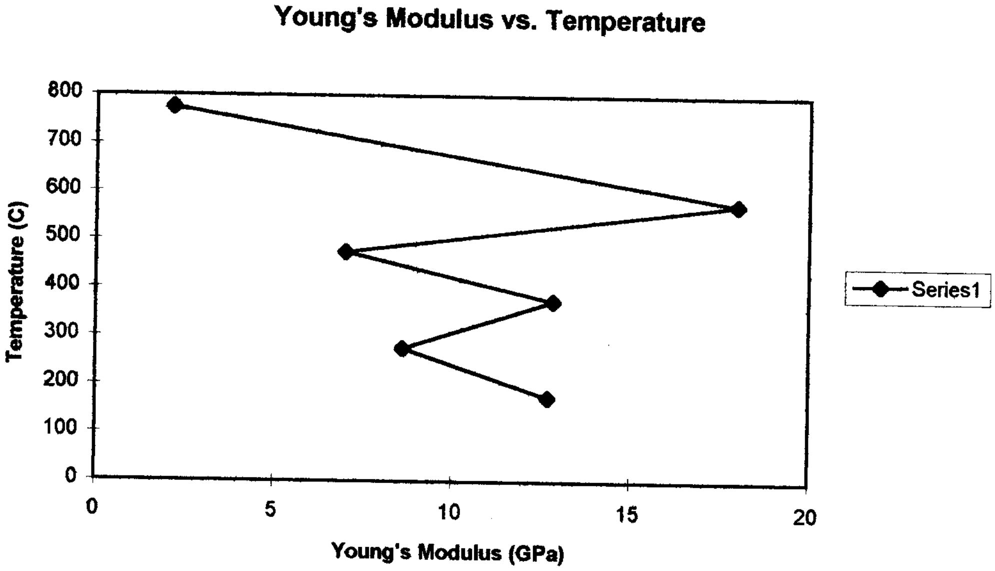

Figure 5 displays Young's Modulus versus the annealing temperature for brass.

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Discussion:

Figure one shows percent elongation is increasing with temperature which is exactly what was expected. From figure two, it is apparent that annealing temperature does not have an effect on hardness until the recrystallization stage of the annealing process. It appears the recrystallization stage begins at the point on the graph where the graph changes from a flat region to a sloped region. In figure two, this happens to be at ~ 300-^{0}C or ~ 598K, which corresponds to a homologous temperature of 0.501 T_m, which is relatively close to the 0.3 T_m - .5 T_m expected value.

Both yield strength and tensile strength behave similarly compared to temperature. From figures three and four, it is evident that they both decrease in a linear fashion until the stage of grain growth is reached. At that time, yield strength and tensile strength begin to level off as the temperature increases.

In theory, the annealing procedure should not have an effect on Young's modulus, but the results of this experiment do not confirm nor refute this theory. The compounding errors in this experiment produce data that reveals a large deviation in the calculation of Young's Modulus.

By doing nearly 70% cold work on these brass samples, the hardness was relatively high for the material. As the percent cold work increases, the hardness also increases. It is impossible to recrystallize a material without first cold working it.

DISCUSSION OF HOW MICROSTRUCTURE RELATES TO PROPERTIES?

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Conclusion:

A major reason for annealing is to recover the ductility of a material. From the results of the hardness tests, it can be confirmed that annealing beyond the recovery stage has an effect on the hardness of brass. Also, yield strength and tensile strength are affected by annealing until the stage of grain growth was reached. Following this point, the effect of annealing is minor. These results, within the error limits, are what was expected. Additionally, we determined our homologous recrystallization temperature to be 0.501 T_m which is extremely close to anticipated values.

References:

Department of Chemical Engineering and Materials Science. University of California, Davis. Properties of Materials Laboratory. Fall Quarter, 1996.

Shackelford, James F. Introduction to Materials Science for Engineers, Fourth Edition. Simon & Schuster. Upper Saddle River, New Jersey. 1996.

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