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Title: Tensile Testing

Abstract

The report discusses the use of the results gathered by a tensile testing machine in order to define mechanical properties of materials. The stiffness of the testing machine, the engineering and true stresses and strains were calculated. Also, the Young's Modulus, yield strength, ultimate tensile strength, percent elongation, and strain to failure for the provided specimens were determined. Three identical specimens of 7075-O and 7075-T6 aluminum alloys were tested but the heat treatment was the different in each one. The mechanical properties that were resulted by the heat treatment were analyzed. The results showed that 7075-T6 had higher strength and lower ductility than 7075-O. The relationship of the heat treatment with the results was discussed, as well as, the relationship of the dislocations and recrystallization with the results were explained.

Introduction

The importance of studying the effects of annealing on ductile metal, such as Aluminum, is that it can produces different mechanical properties of the metal which can be applied beneficially as desired to commercial and other engineering applications.

The definition of Anneal is “to heat and then cool (a material, such as steel or glass) usually for softening and making less brittle; also :to cool slowly usually in a furnace” (Merriam-Webster).

Based on the definition, the annealing process uses the heating and cooling processes for the material, such as Aluminum, in order to make it soft and less brittle. As a result, the process

strengthens and toughens the specimen to the desired level by controlling the amount of heat and time as well as the rate of cooling.

The annealing test in this experiment used to compare high and low strength Aluminum specimens, 7075-T6 and 7075-O respectively. The strength of a third 7075-O specimen was compared before and after hardened by the tensile test machine.

Procedure

Three specimens of 7075 Aluminum are provided. They were cold-worked before the laboratory is started to apply the tensile test on each of them. Two of the three specimen are annealed by heating to 415 C for 3 hours. The thickness and the width of each specimen are measured with a micrometer and recorded in Table 1

The first specimen is the cold worked, 7075-O. it is placed in position and connected to the tensile test machine. To ensure that the specimen is not going to slip, the jaws were tightened. The extensometer then attached to the specimen 2 inches of initial length. The crosshead speed is set at 0.1 in/min (slow and constant). The test starts applying tension to the specimen until it failed. The data is recorded by the computer to be in a spreadsheet.

In the second test, the same is done to the annealed specimen, specimen two, for comparison.

In the third and last test, the specimen is wok-hardened. First, the specimen subjected to the tension by the machine just before its yield point, where the specimen is still in the elastic deformation range. After relieving the tension, the specimen is expected to return to zero stress.

The load is applied again until failure. The computer recorded the data in a spreadsheet.

Results and Discussion

The test data recorded by the computer were used to calculate the engineering stress by the following equation

$$s = \frac{P}{A_o}$$

where (P) is the load, (A_o) is the initial cross sectional area of the specimen, and (s) is the engineering stress.

From the data recorded, the engineering strains are calculated by two equations. The first equation is done by using the displacement of the cross arm as following:

$$e_1 = \frac{\Delta L}{L_o}$$

where e_1 is the engineering strain measured from the cross arm displacement, L_o is the guage length measured on the specimen and ΔL is the cross arm extension.

The second equation that used to determine the engineering strain is using the extensometer displacement as following:

$$e_2 = \frac{(L_2 - L_{20})}{L_{20}}$$

where L_{20} is the extensometer knife edge separation before tensile test (2 inches), L_2 is the extensometer knife edge separation at any time during the tensile test, and e_2 is the engineering strain measured from the extensometer.

Also, from the recorded date, the true stress and true strain are calculated using the following equations:

$$\sigma = \frac{P}{A} = s(e_2 + 1)$$

$$\varepsilon_1 = \ln\left(\frac{\Delta L + L_o}{L_o}\right) = \ln(e_1 + 1)$$

$$\varepsilon_2 = \ln\left(\frac{L_2}{L_{20}}\right) = \ln(e_2 + 1)$$

where σ is the true stress, A is the instantaneous cross sectional area of the specimen, ε_1 is the true strain measured by cross arm displacement, and ε_2 is the true strain measured by the extensometer.

The data of the first and second tests is used to compare both samples for the true stress and true strains ε_2 as shown in Figure 1.

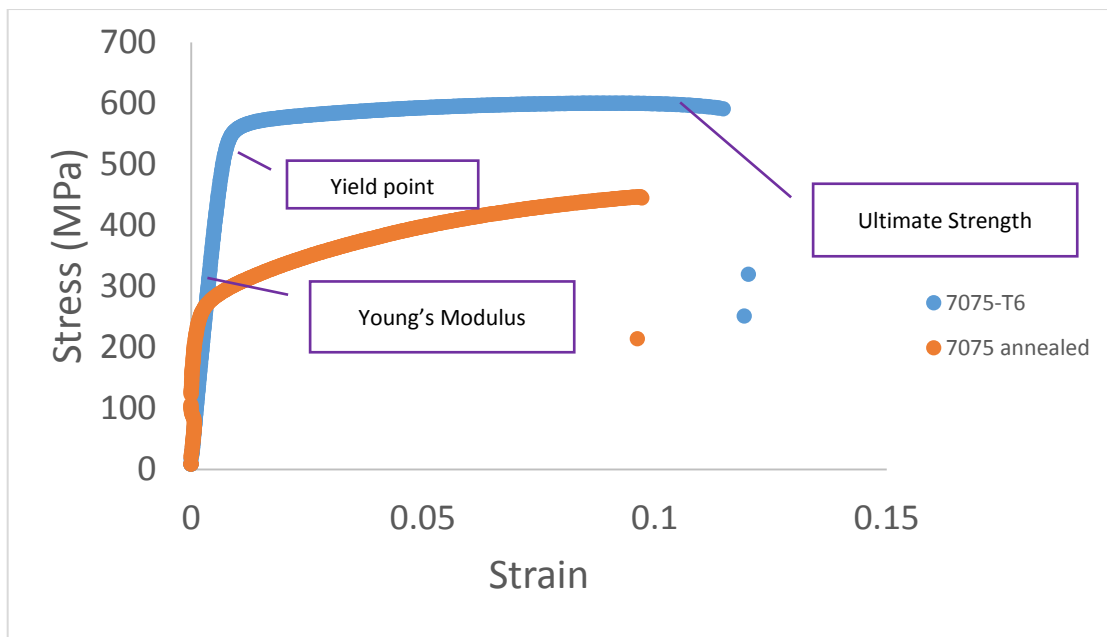


Figure 1 the true stress and true strains ε_2 of the first and second samples

From the previous plot, the values of Young's Modulus, yield strength, ultimate tensile strength, percent elongation, and strain-to-failure can be defined and compared for both specimens. It can

be noted that the stress resulted for the annealed specimen has lower stress by comparing it to the T6 specimen.

The data of the second and third tests is used to make the plot curves of engineering stress versus engineering strain as shown in Figure 2.

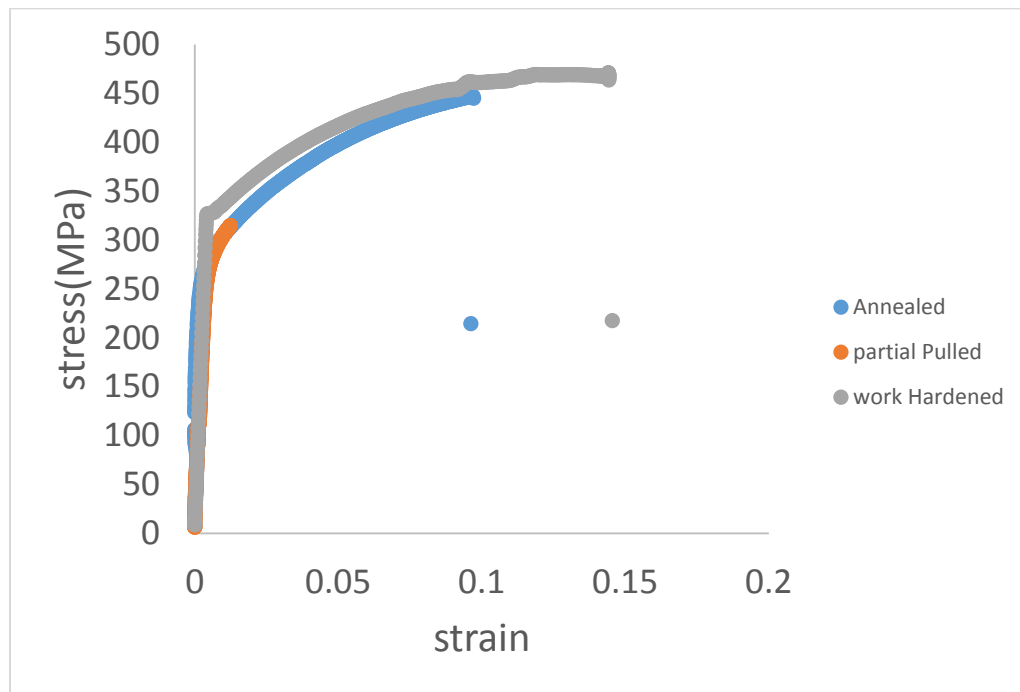


Figure 2 engineering stress versus engineering strain

From the collected data of the first specimen, the engineering and the true stress are compared by plot in Figure 3

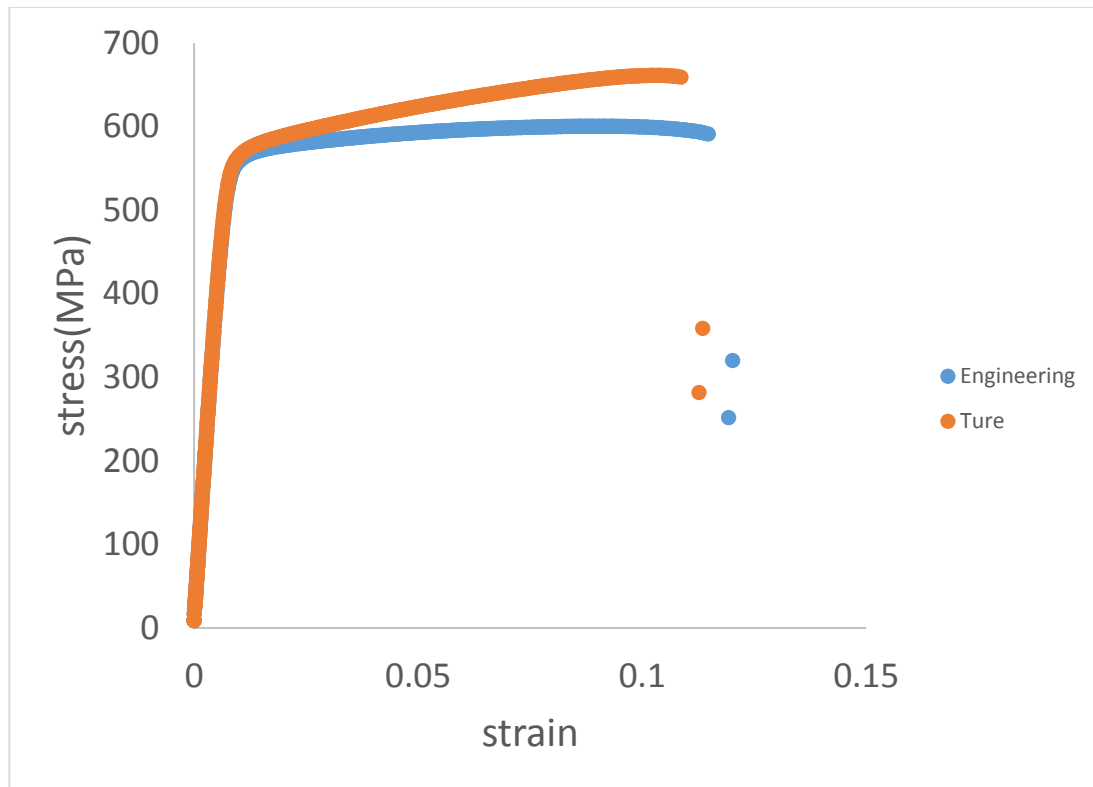


Figure 3 the engineering and the true stress

The following figure, Figure 4, shows the comparison between the true strain measured by the cross arm displacement ϵ_1 and the true strain measured by the extensometer ϵ_2 for the first specimen.

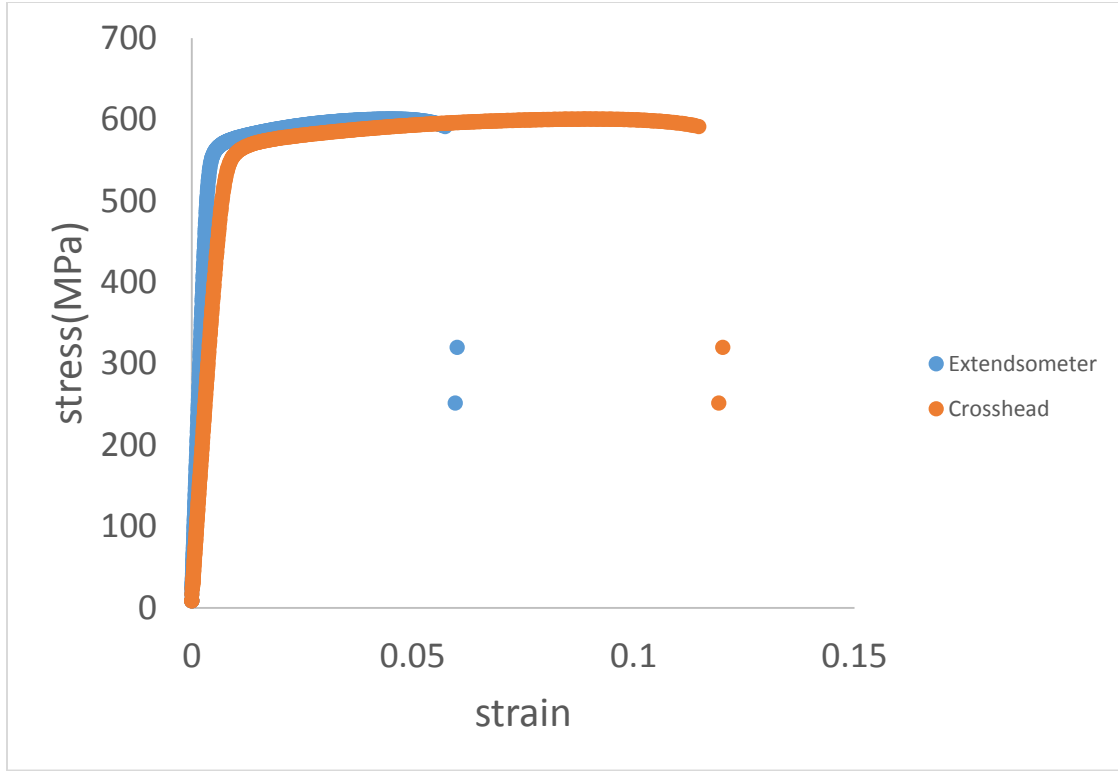


Figure 4 the true strain measured by the cross arm displacement ε_1 and the true strain measured by the extensometer ε_2

As the above figure shows, the extensometer measurement is safer to be used. It is also to be noted that the cross head measurement is not going to be accurate due to the elastic deformation of the test machine.

By using the data of the first sample. The stiffness of the machine is to be determined by using the following equations:

$$\Delta L = vt$$

$$D_e = s * e_1 = s \frac{L_o}{E}$$

$$D_m = \frac{P}{K}$$

The following graph, figure 5 of vt vs. P is showing the machine stiffness K determination:

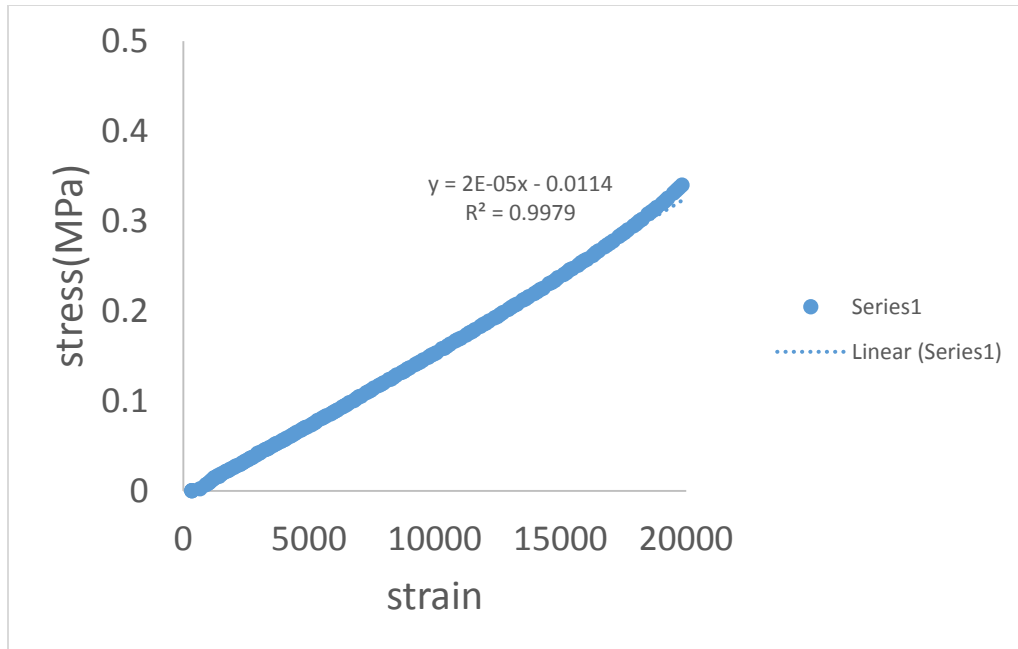


Figure 5 machine stiffness K

The values of the yield strength, ultimate tensile strength and strain-to-failure of the first and second samples are compared with the literature values gained from Appendix B of the textbook.

Conclusion

After performing the experiment, it is concluded that the heat treatment of alloys has higher strength than the fully annealed alloys because the fully annealing alloys remove any previous strain hardening. The fully annealing is the cause of that, basically, because it allows the recovery and recrystallization of larger grains associated with no dislocation pile-ups. The result of that will affect the mechanical properties of the material, and so, the slip will be at lower stress and the dislocation will move longer before reaching the grain boundary. In contrast, the cold-worked Aluminum alloy has low strength and high ductility.

Also, the strain measurement by the displacement of the crosshead is going to result a serious error because of the elastic deformation of the tensile machine. The elasticity deformation of the machine is proportional to its stiffness. The reading of an extensometer can be used to avoid similar error.

References

1. “Anneal.” Merriam-Webster, Merriam-Webster, www.merriam-webster.com/dictionary/anneal.