Lab Experiment # 6

Precipitation Hardening of Aluminum Alloys

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Objective

In the Precipitation Hardening of Aluminum Alloy lab, changes made in the hot treatment of aluminum alloy is done to determine the changes in mechanical properties of aluminum alloy. 3 different temperature is used to determine the changes in the hardness. Changes are also examined during difference in time

Equipment/Materials

- Furnace
- Rockwell hardness tester
- Aluminum Alloy 2024-T351

Experimental Procedure

1. Cut the aluminum specimen into four pieces with the dimensions of 12 x 12 mm. Mark the specimens to keep track of which aging temperature will be used for each
2. Perform a Rockwell hardness test of each specimen and take the average value as the initial hardness of the aluminum alloy before the treatment process
3. Place three of the specimens into the furnace at a temperature between 510-540 ^{o}C for 45 to 60 minutes.
4. Once the time is up, place all the specimens quickly into water for the quenching process.
5. Take the average hardness after quenching as the hardness value after quenching.
6. During the aging stage, place one specimen into the freezer at -18 ^{o}C for 2 weeks. Place one in room temperature at 25 ^{o}C and one back into the furnace at a temperature of 190 ^{o}C
7. Take the hardness level of specimen and compare values.

Experimental Results

Aging Method Rockwell Hardness (HRB)				
	Reference	Natural	Artificial	Cold Aging
Before Heat Treatment	75.333	77	74.667	77
After quenching		45	51	45
After Aging (2 Weeks)	74.667	75	70.333	50.667

Figure 1: Average Hardness Values of each specimen with different aging temperature. Artificial tempering corresponds to a temperature of 190 ^{o}C, cold aging temperature of -18 ^{o}C and Natural at 25 ^{o}C.

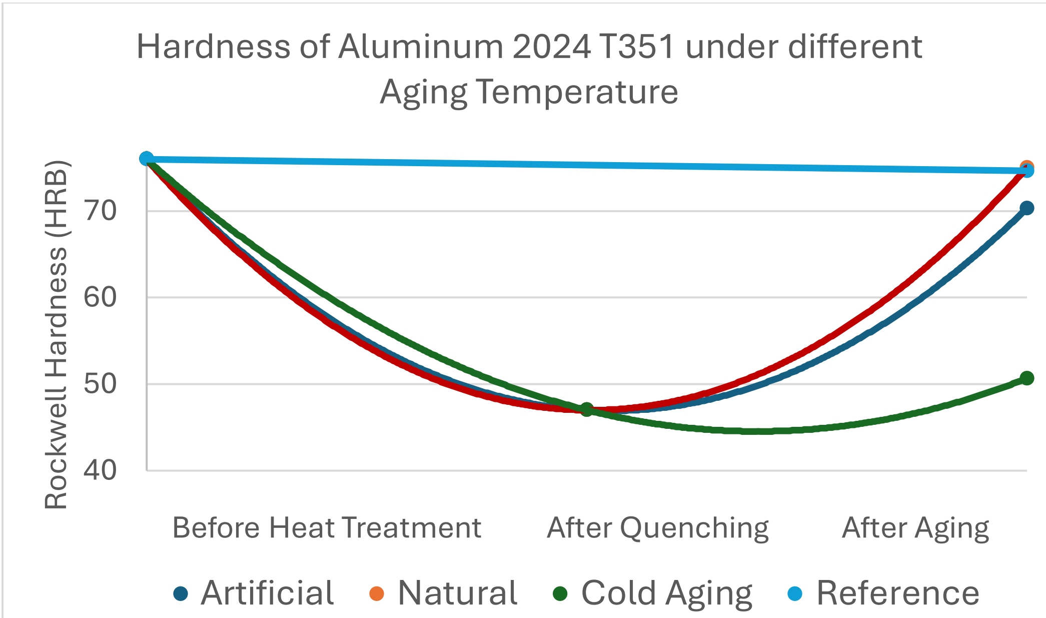

Figure 2: Plotted Average Hardness level of 4 specimens under different aging temperature. Artificial tempering corresponds to a temperature of 190 ºC, cold aging temperature of -18 ºC and Natural at 25 ºC.

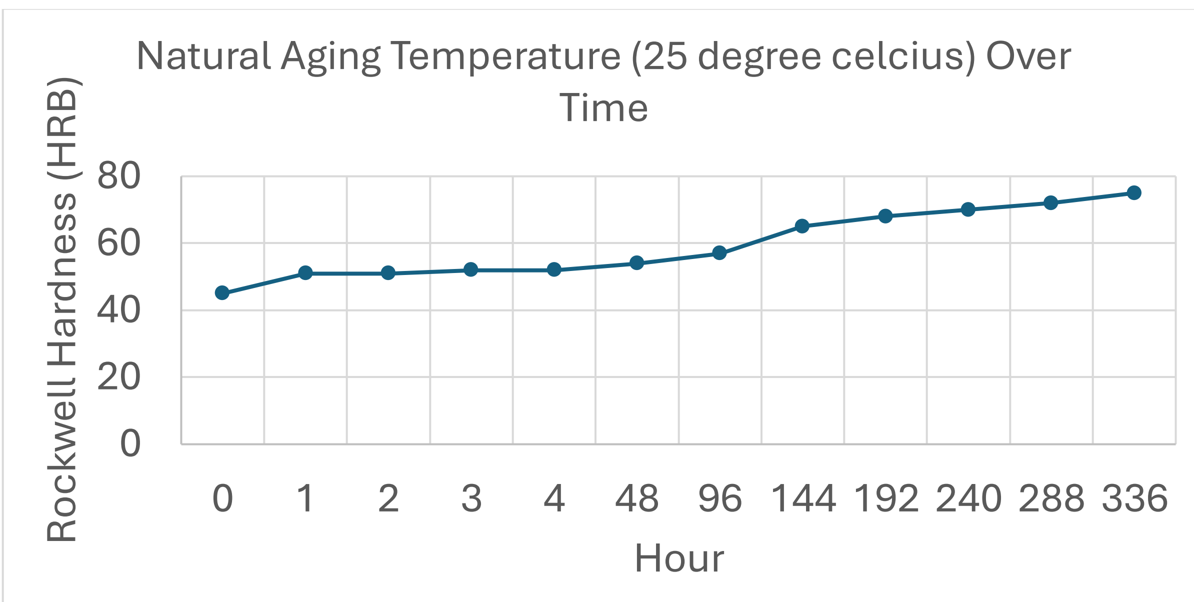

Figure 3: Hardness level of Natural aging temperature specimens after different time to 2 weeks.

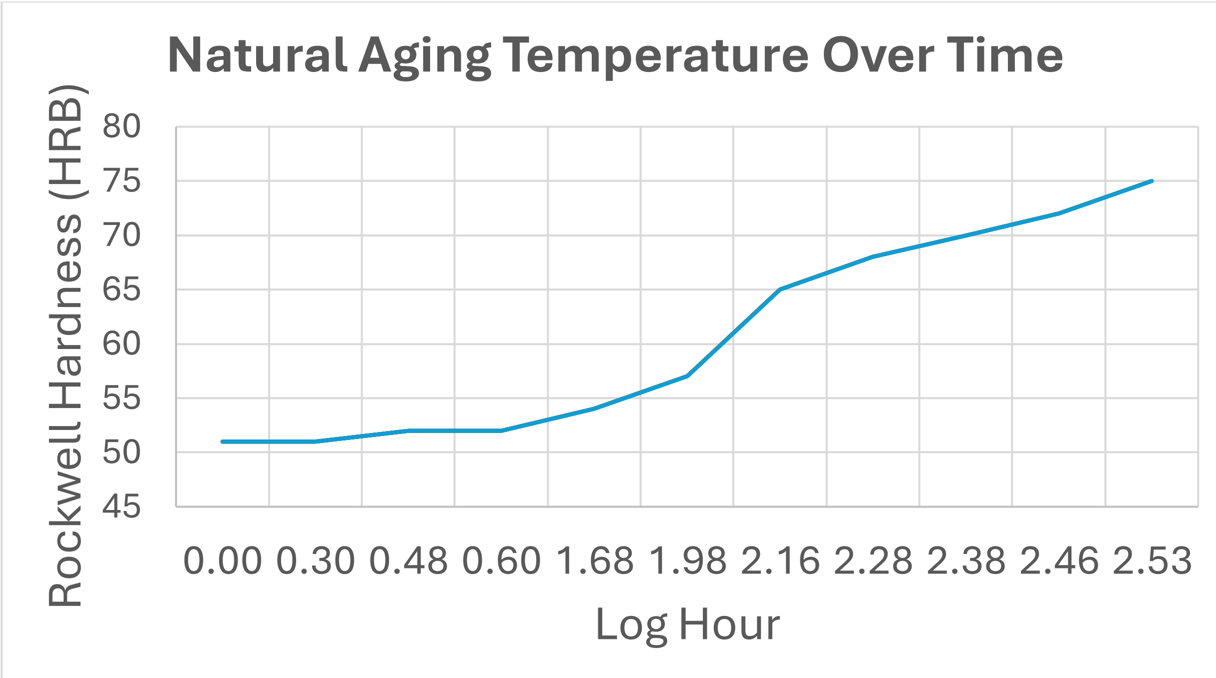

Figure 4: Hardness level of Natural aging temperature specimens at the log hours for the period of 2 weeks.

Discussion of Results

From the results of figure 2 (tabulated values in figure one), quenching process was seen to drastically decrease the hardness of the aluminum alloy. The process of aging post quenching is seen to recover the hardness values. From the experiment, freeze aging is seen to recover the least amount of hardness at only a HRB value of 50.667 with the room temperature at a value of 75. Time is also a important factor seen through the natural aging specimen. The recovery of hardness increased within the 2 weeks post quench with the initial value at 45.

The drop in hardness due to quenching because the metastable structure becomes soft during the rapid change in temperature. During this step, the alloying element (copper) are being trapped in the solid solution. Alloy can then be heated at a low temperature in the aging process to allow for precipitation of fine particles. While in this lab it was found that room temperature left for longer time yielded the best hardness recovery, use of an artificial aging temperature may be used in application to reduce time needed for recovering hardness.

Conclusion

The process of Precipitation for Aluminum Alloy is used to strengthen the material by increasing strength, hardness and toughness of the material. In this lab, the change in hardness is explored through the effects of time and temperature on the Rockwell hardness. During the aging process, it was found that the Natural aging temperature after two weeks provided the best harness results on par with no aging. Increased temperature for aging was seen to hinder the process of hardening after quenching while increasing time for the room temperature specimen.

Review Questions

1. Briefly explain the purpose of each of the steps involved in the age-hardening process.

The first step of the age-hardening process is the solution heat treatment in which the alloy is heated to a high temperature (in this case of the experiment, between 510-540 ^{o}C). This step is done to uniformly dissolve the alloying elements uniformly.
The second step (quenching) is done to help trap the alloying element, needed to help change the mechanical properties of the host solid.
The final process (Aging) is done to recover some lost ductility from the quenching process by heating to low temperature which varies from purpose and constraint of the needed alloys. Such process can be done with room temperature or an artificial elevated temperature.

2. Why is it important that the specimen (which has just been subjected to solution heat treatment) to be taken very quickly from the furnace and dropped into the quench bath?

Quickly taking the specimen to quench bath due to preference of rapid change of the temperature as it allows for the least amount of time in the alpha beta region in the binary phase diagram.

3. Is it appropriate to place your specimen close to the door of the furnace during solution heat treatment?

To achieve a higher, more uniform temperature, placing the specimen away from the door is a ideal location. Placing specimen near the door may cause uneven heating.

4. What results would be expected if your solution heat treat your specimen of 2024-T3 aluminum alloy at (a) 650^{o}C (1200^{o}F); (b) 550^{o}C (1025^{o}F); (c) 425^{o}C (800^{o}F)?

At a higher temperature, 650^{o}C, increased ductility but lower strength is expected due to its high value. At 550^{o}C, some hardness and strength properties are achieved and with 425^{o}C, the specimen may not achieve the desired hardness.

5. What is the role of solid-state diffusion in the precipitation hardening process?

Solid state diffusion role is to primarily increase the material properties (enhance the strength) by creating precipitates which ultimately block dislocation movements and therefore the plastic deformations.

6. What is the difference between coherent and noncoherent precipitates?

Coherent precipitates have nearly perfect lattice structure while a noncoherent has no matching interfaces causing distortion in the lattice structures.

7. Using your results as a reference, explain the meaning of the term "incubation period."

Incubation period can be seen as the time in which it takes for the recovery of hardness during the aging of the specimen under room temperature. While hardness significantly decreases during the quenching process, the increase in time after quenching can be seen to recover the hardness to around the pretreatment values.

8. Using your results as a reference, can you predict how the hardness versus aging time curve would change for different aging temperature?

Aging temperature curve should generally go down in the same curve slope as temperature increases. It can be seen with the lowest temperature, freezing at -18 ^{o}C, the recovery is seen to be the least but in the same manner of recovery.

9. Why are the rivets made of heat-treatable aluminum alloys stored in dry ice before riveted into place?

Placing rivets in dry ice can help to preserve mechanical properties in order to ensure hardening prior to usage. Principates may form at lower rates, ensuring the hardness can be stalled.

10. Does the cold forming of an aluminum alloy, which has been solution heat treated and quenched, have any effect on the age-hardening process? Why?

Cold forming may allow for more opportunity for precipitates to form thus overall slowing down the age-hardening process.

11. During artificial aging, if the specimen in left for a longer time (over-aged), how would this affect its hardness and its microstructure?

Over aging may cause the hardness to decrease and the microstructure will become more fine. Yield strength may increase to a certain point and once over aging is achieved, the increase in time produces an opposite, undesired result.

References

[1] CCNY ME 46100 Lab Report Preparation, CUNY blackboard website.
[2] CCNY ME 46100 Lab Manuals, CUNY blackboard website.
[3] CCNY ME 46100 Lab Data, CUNY blackboard website.