IME-301
Dr. Laura Sullivan
Thursday 1:20pm

LAB #1 PART B

Team Members

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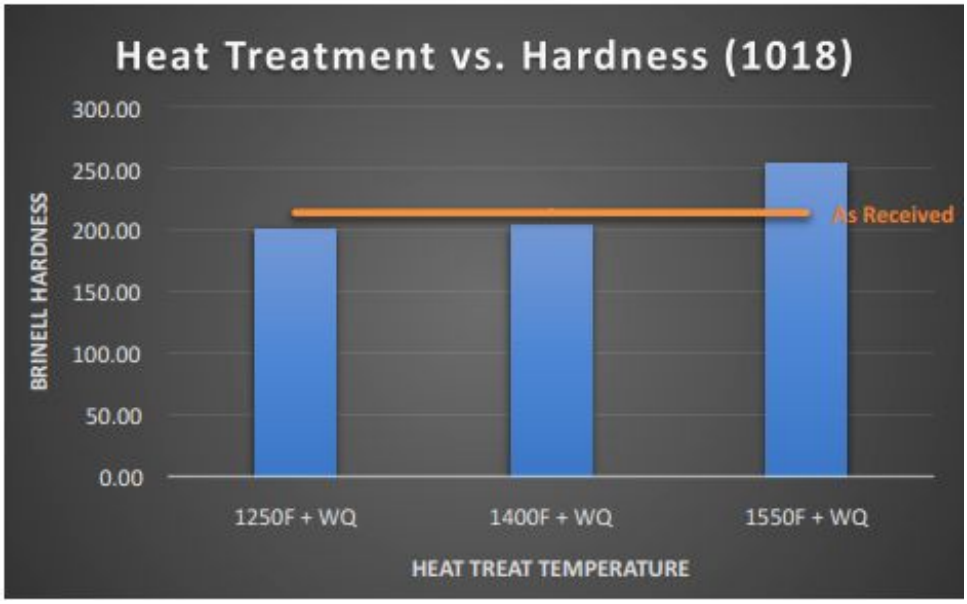
Friday, June 2, 2017

Objective

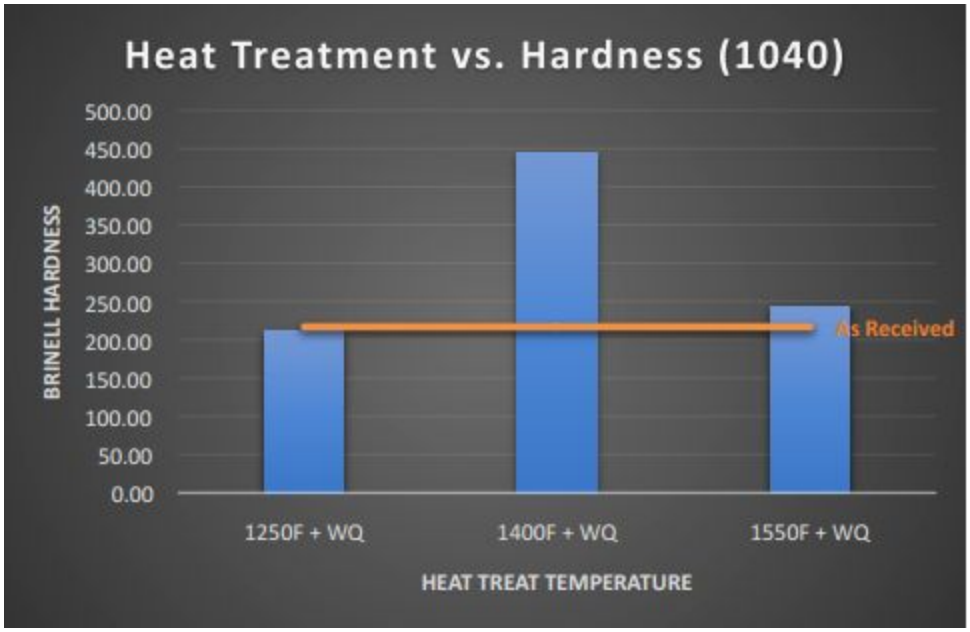
1) Discuss the effect of % Carbon and presence of alloy elements on properties following anneal + quench. **For 4 steels and after 3 temperatures**
    a) Hardness
    b) Yield strength
    c) UTS
    d) Modulus

2) Discuss effect of anneal temp on properties **for each steel**

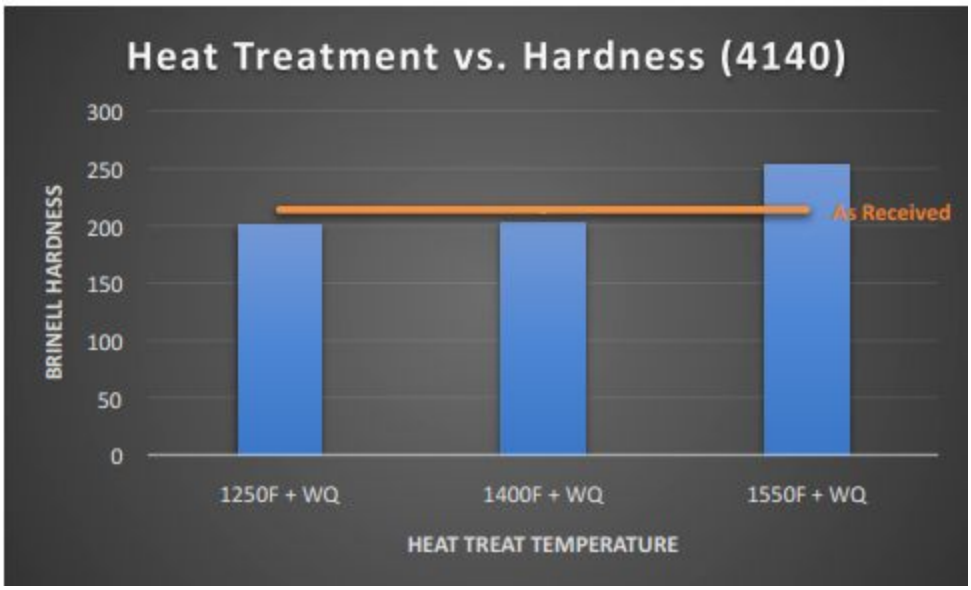
1) a) Hardness



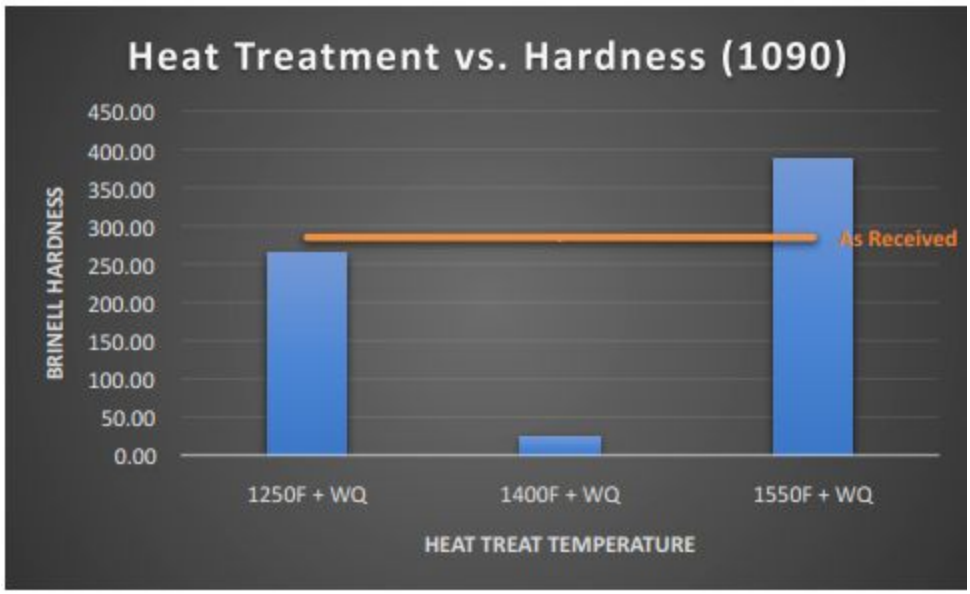
From the FeC phase diagram we can see that at 1250º F we are below the eutectic temperature so no hardening can occur no matter if quenched or not. The only process that can occur is annealing. Moving to the 1400º F we are above the eutectic temp so some gamma is produced but still mostly alpha will be present and that is why you do` not see any hardness effects when quenched. At 1550º F the metal has transitioned into the full gamma phase this allows the maximum hardness to be achieved when water quenched.



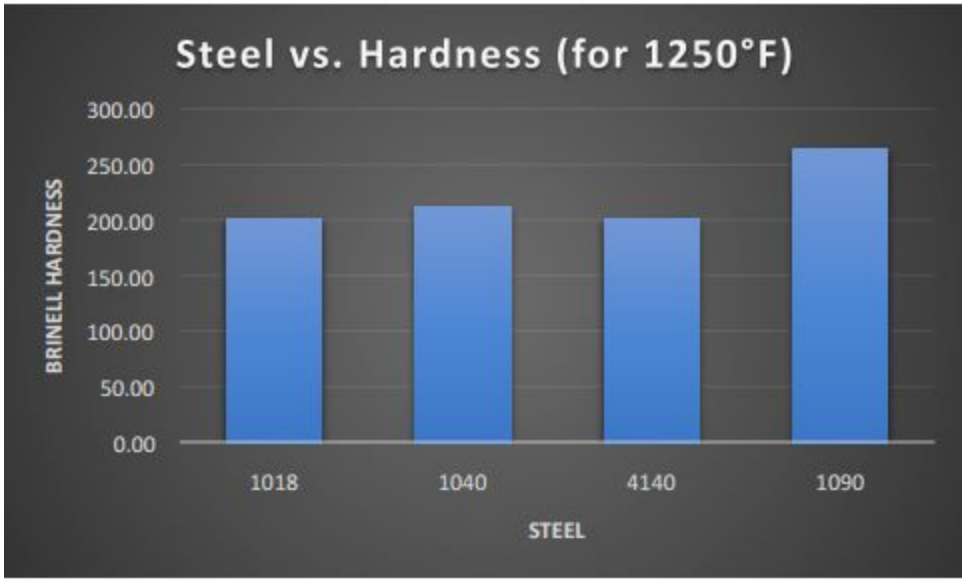
1040 steel water quenched at 1250º F yields Ferrite and Fe_3C. Quenched at 1400º F it has a different phase combination of Ferrite and Austenite. Quenched at 1550º F it becomes only Austenite. The combination of Ferrite and Austenite at 1400º F has the highest hardness.

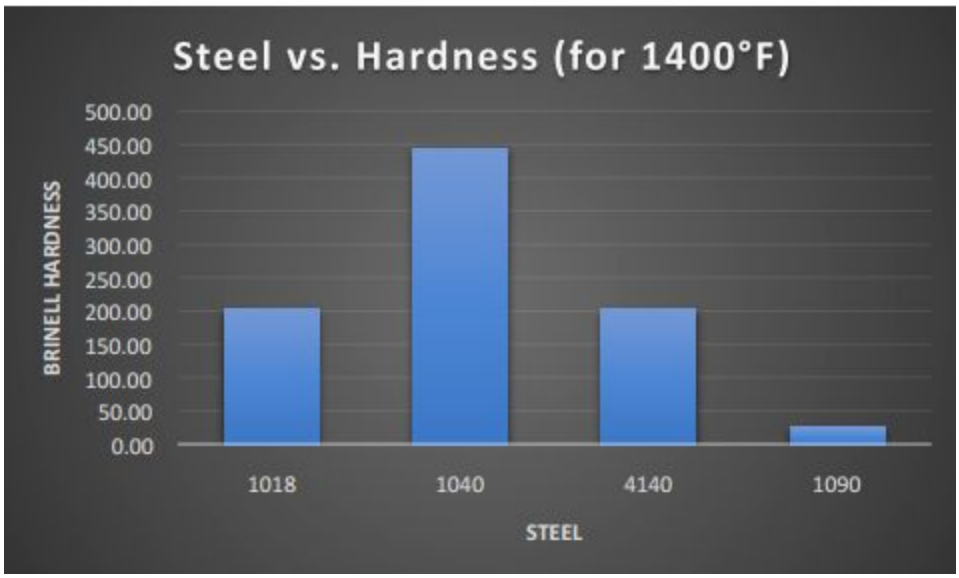


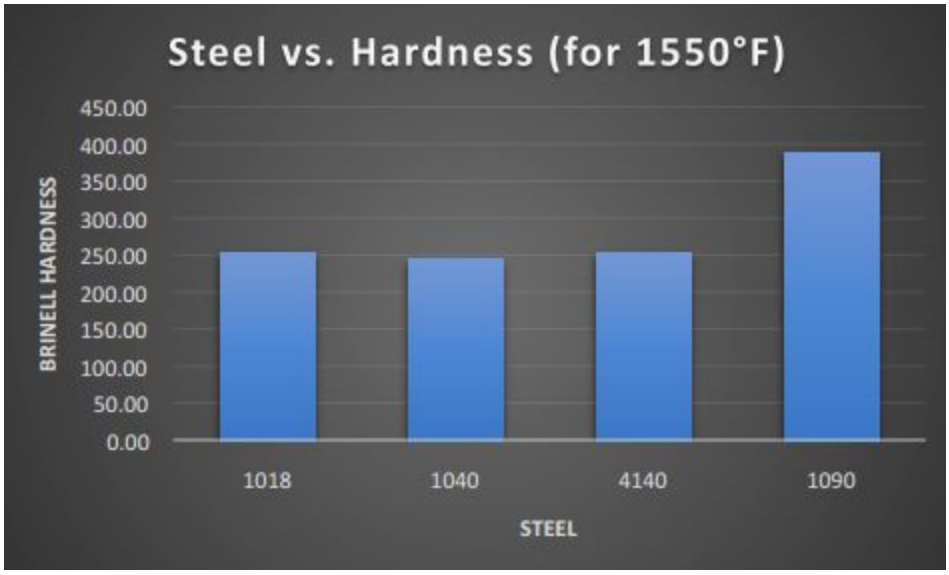
The 4140 material differs from the 1040 because of the addition of alloying materials, in this case, primarily molybdenum. The difference in hardness of the material is that 1550º F water quenched yields a higher hardness than the other phases including the as received.



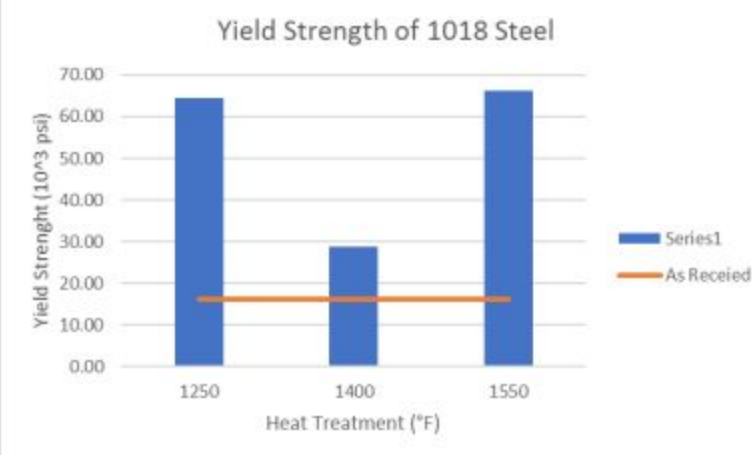
For the 1090 steel we will need to look at the 0.9wt%C on the FeC phase diagram. Again like above for the 1250º F sample we do not reach the eutectic reaction temperature so no changes will be observed. When going to the 1400º F we reach a temp above the eutectic temperature where we should see some gamma being produced and a hardness effect. The plotted reaction seen above seems to be data the does not accurately represent expected results. At 1550º F the metal should be fully gamma so we do see the increased hardness when water quenched. The 1400º F sample could show skewed results because of failure to quench fast enough for the creation of austenite.



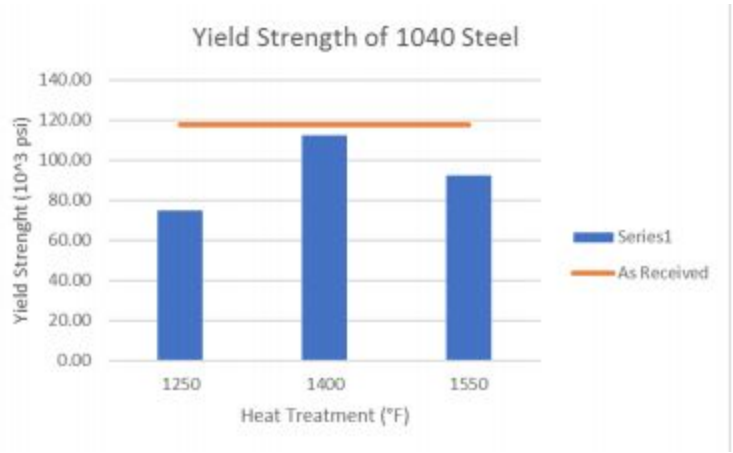

Steel vs. Hardness (for 1400°F)
BRINELL HARDNESS
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
1018
1040
4140
1090
STEEL


Steel vs. Hardness (for 1550°F)
BRINELL HARDNESS
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
1018
1040
4140
1090
STEEL

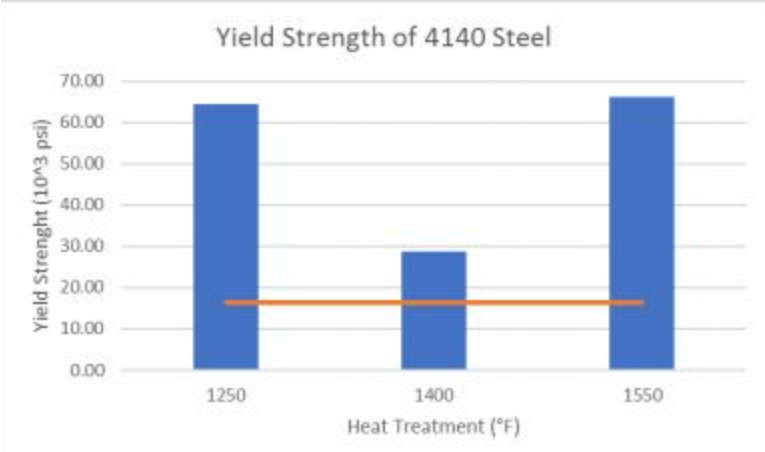
1) b) Yield Strength



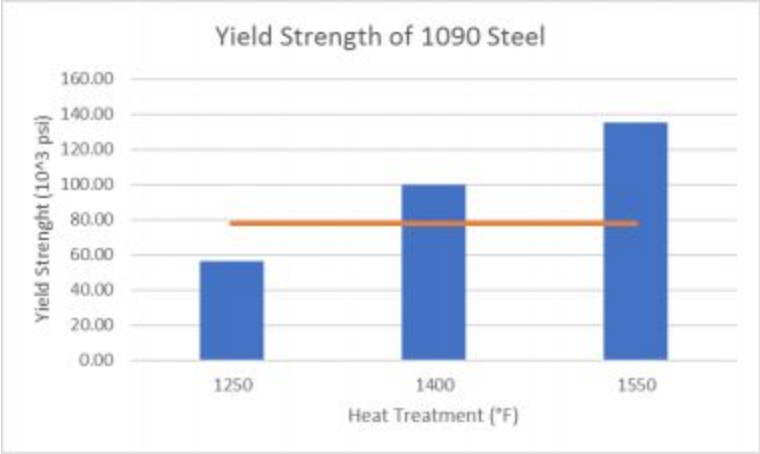
When analyzing the yield strength for 1018 steel we can see how the values of the 1250º F we have increased the yield strength over the as received specimen. This could be because the heating allowed for recrystallization to occur, increasing the ductility of the metal. For the 1400º F the sample has decreased in yield strength, and then at 1550º F the yield strength returns to the same result as 1250º F. Due to the lower carbon content at the 1400º F we continue to soften and not until we reach 2550º F do we see the yield strength start to rise.



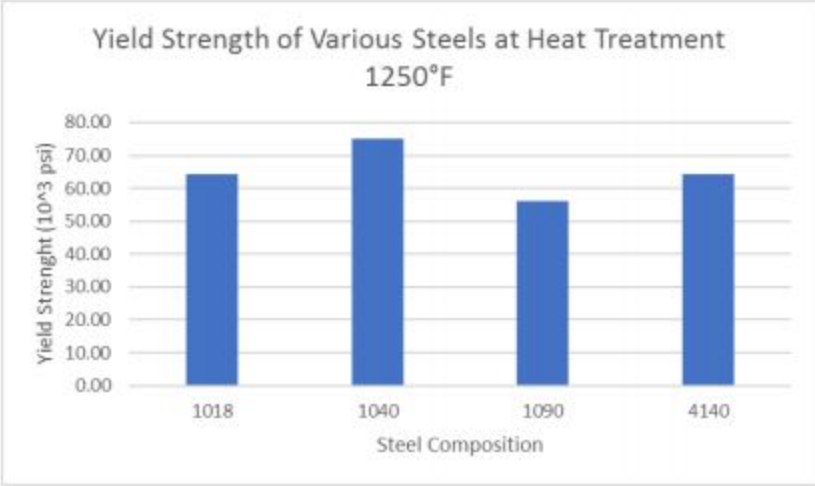
The yield strength of 1040 steel is highest when quenched at 1400º F which creates a combination of Ferrite and Austenite. This combination is very close to the as received yield strength value. Yield strength of the Ferrite and Cementite is lowest.

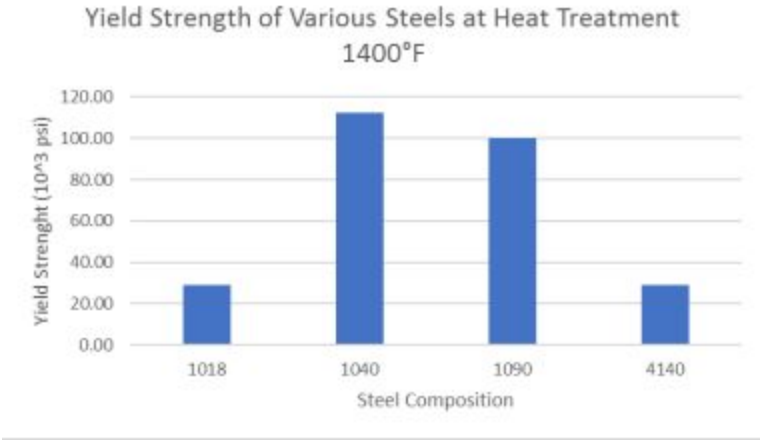


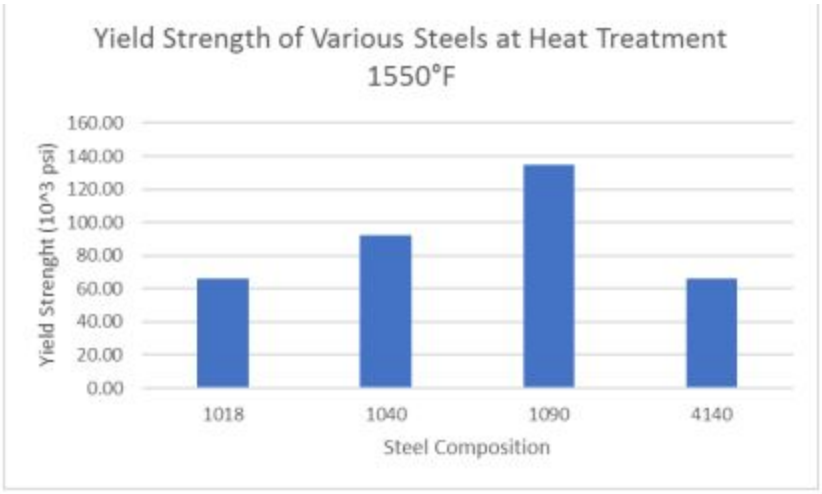
This graph is interesting because the 1250º F and 1550º F heat treated steels created much higher yield strengths for the Ferrite-Cementite and for the austenite. However the ferrite-austenite for the 4140 steel has the lowest yield strength, which is opposite of the 1040 steel.



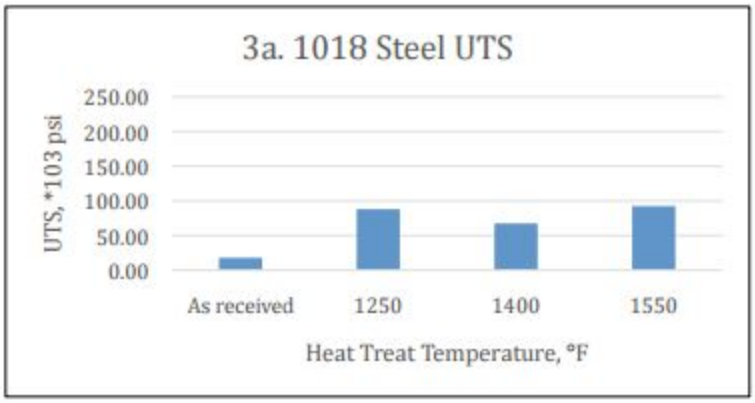
For 1090 steel with the higher carbon percentage we see the decreased yield strength at 1250º F because there is only annealing that occurs. When increasing the temperature we can see the yield strength increasing because of the austinite that is being formed.


Yield Strength of Various Steels at Heat Treatment
1250°F
Yield Strenght (10^3 psi)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1018
1040
1090
4140
Steel Composition

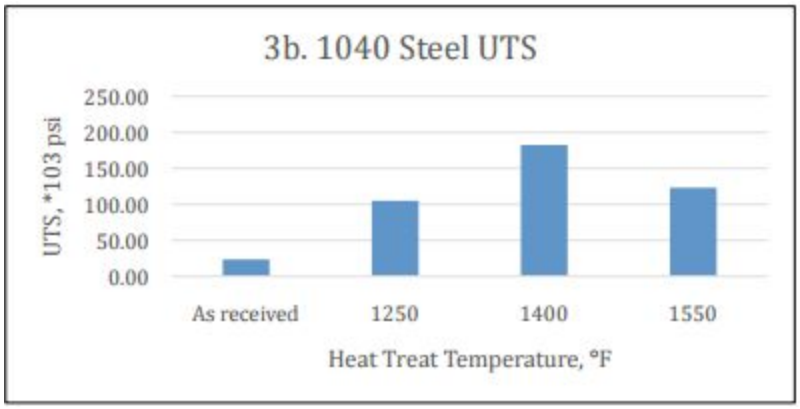

Yield Strength of Various Steels at Heat Treatment
1400°F
Yield Strenght (10^3 psi)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1018
1040
1090
4140
Steel Composition



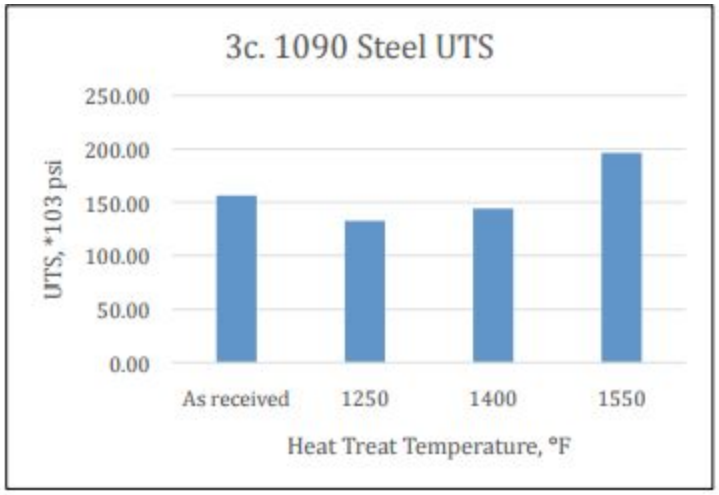
1) c) UTS



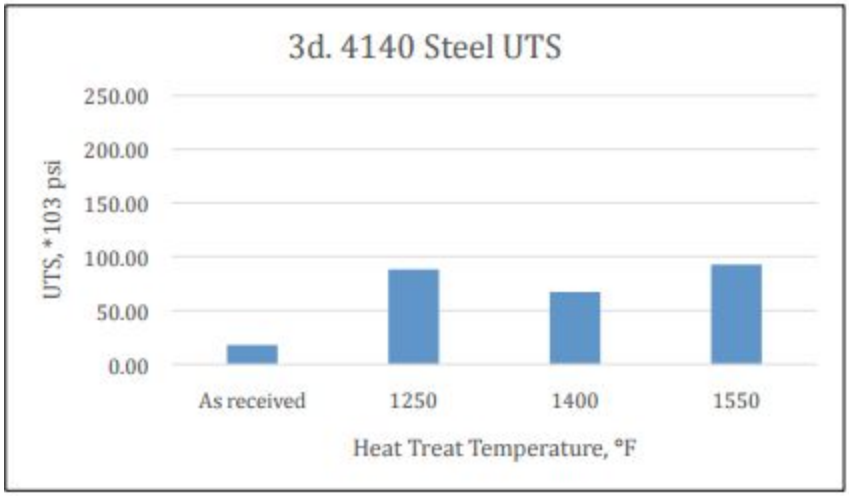
This graph demonstrates the differences in Ultimate Tensile Strength of the different phase combinations of 1018 steel. As received has the lowest UTS, but when heat treated to the different temperatures yields three different phase combinations with different UTS based off the compositions.



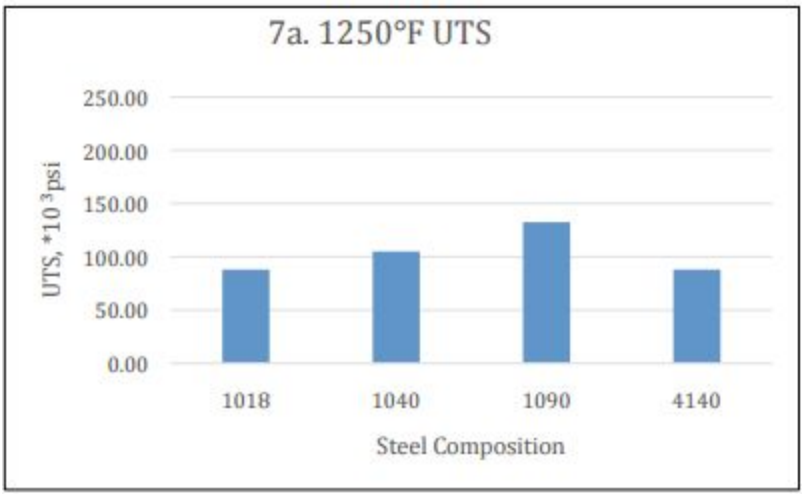
1040 steel responds differently to the heat treating process. The graph shows a bell curve effect with the peak UTS for 1040 steel a result of the heat treatment process at 1400º F. This phase is Ferrite and Austenite.

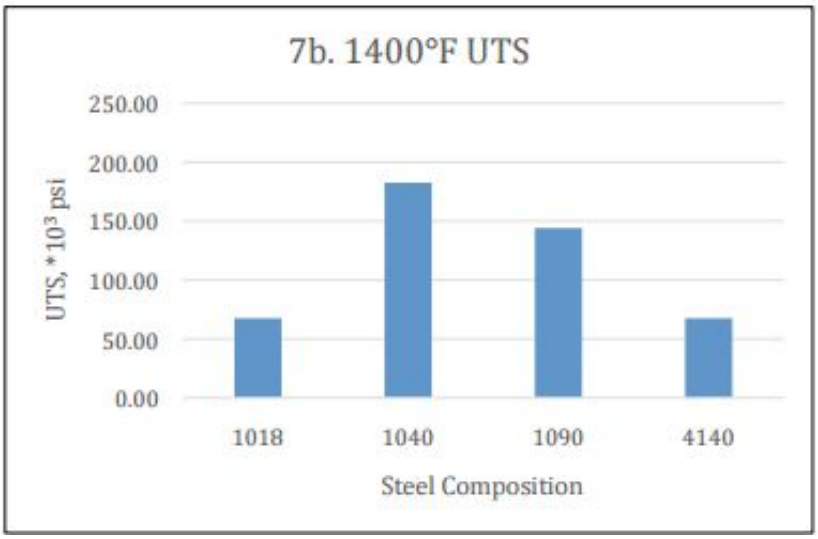


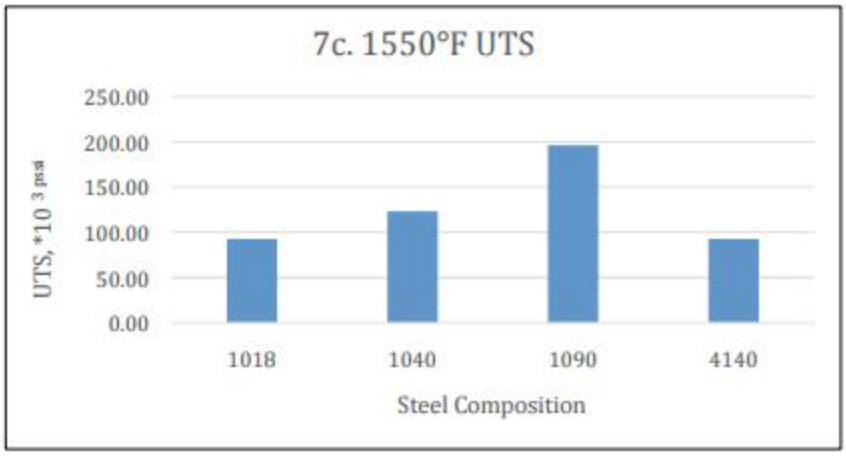
The 1090 Steel does not change UTS with different heat treatments when compared to the other steel samples. The high carbon content steel still proceeds through three different phase combinations with the different heat treatment processes which trends towards increasing UTS with high temperatures.



4140 steel dips in UTS at 1400 heat treatment similar to the 1018 Steel. In fact, the graph for 4140 is nearly identical to the 1018 UTS graph.

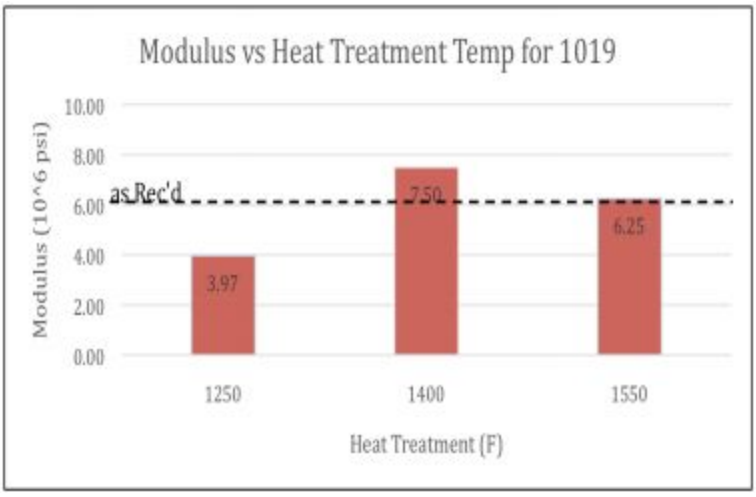

7a. 1250°F UTS
250.00
200.00
150.00
100.00
50.00
0.00
UTS, *10 3psi
1018
1040
1090
4140
Steel Composition

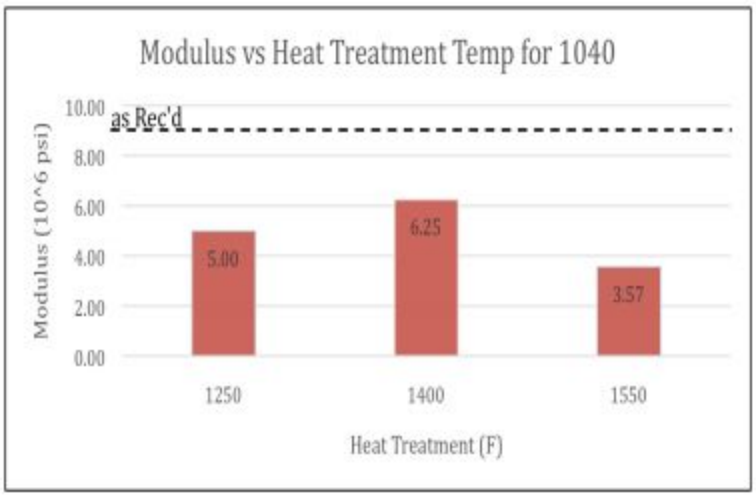

7b. 1400°F UTS
250.00
200.00
150.00
100.00
50.00
0.00
UTS, *10³ psi
1018
1040
1090
4140
Steel Composition

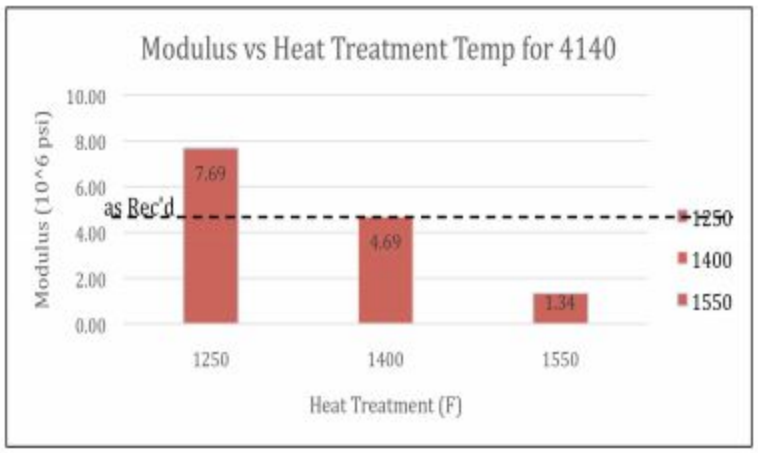

7c. 1550°F UTS
250.00
200.00
150.00
100.00
50.00
0.00
UTS, *10 3 psi
1018
1040
1090
4140
Steel Composition

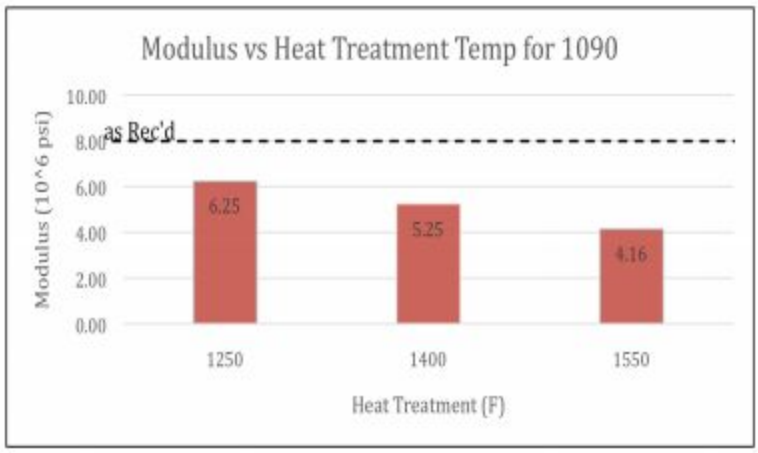
1) **d) Modulus**

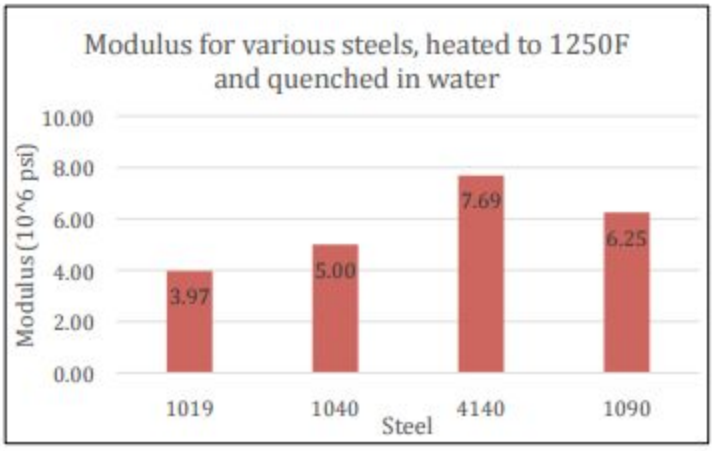
Modulus is a ration of the stress and strain we would not expect to see changes in the modulus based on heat treat. The difference that are seen below in the plots can be attributed to the error in calculation and reading the tensile test of the specimen.

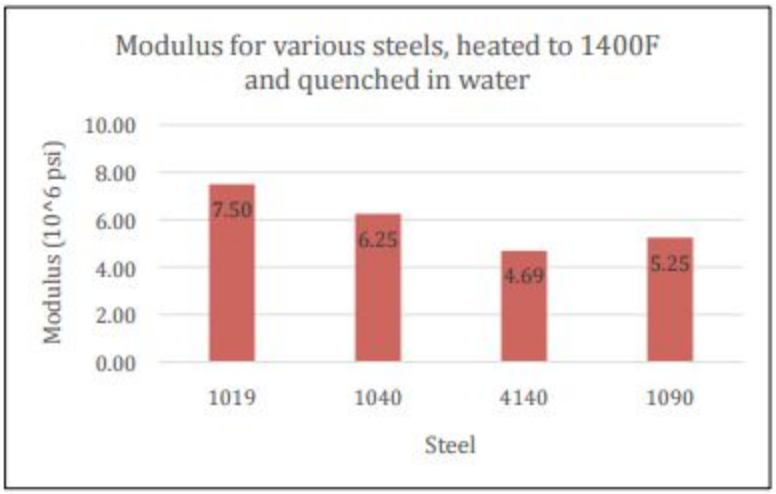


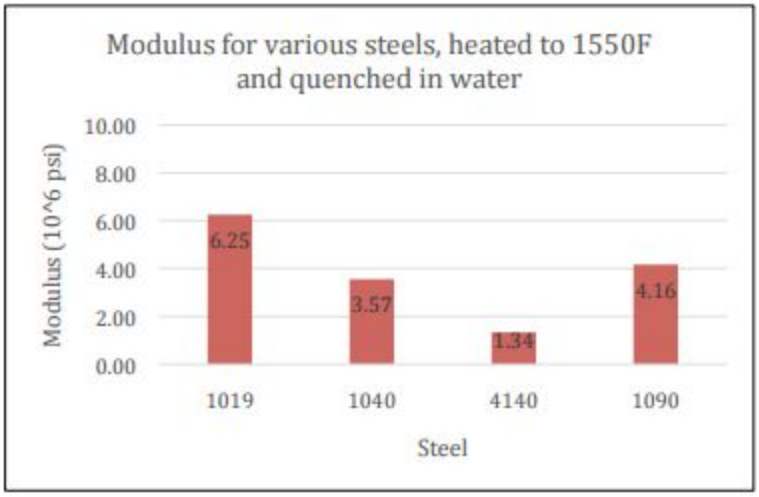



Modulus vs Heat Treatment Temp for 4140
Modulus (10^6 psi)
10.00
8.00
6.00
4.00
2.00
0.00
as Rec'd
7.69
4.69
1.34
1250
1400
1550
Heat Treatment (F)
1250
1400
1550


Modulus vs Heat Treatment Temp for 1090
Modulus (10^6 psi)
10.00
8.00
6.00
4.00
2.00
0.00
as Rec'd
6.25
5.25
4.16
1250
1400
1550
Heat Treatment (F)


Modulus for various steels, heated to 1250F and quenched in water
Modulus (10^6 psi)
10.00
8.00
6.00
4.00
2.00
0.00
3.97
5.00
7.69
6.25
1019
1040
4140
1090
Steel


Modulus for various steels, heated to 1400F and quenched in water
Modulus (10^6 psi)
10.00
8.00
6.00
4.00
2.00
0.00
7.50
6.25
4.69
5.25
1019
1040
4140
1090
Steel


Modulus for various steels, heated to 1550F and quenched in water
Modulus (10^6 psi)
10.00
8.00
6.00
4.00
2.00
0.00
6.25
3.57
1.34
4.16
1019
1040
4140
1090
Steel

2) Discuss effect of annealing temp on properties **for each steel**

- **1018: Annealing temperature 1575 and 1650 º F**
  - **Hardness**
    - At 1250 ºF we are below the eutectic temperature so no hardening can occur no matter if quenched or not. The only process that can occur is annealing
  - **Yield Strength**
    - Material 1018 we note similar yield strength values at 1250º F and 1550º F of 65 but for the 1400º F temperature we note a smaller yield strength value of 29.
  - **UTS**
    - Material 1018 at 1550º F received a value similar to 1250º F.
  - **Modulus of Elasticity**
    - No correlation of the modulus of elasticity with anneal temperature

- **1040: Annealing temperature 1600 to 1800°F**
  - **Hardness**
    - Annealing temperature occurs at 1600 to 1800˚F looking at the graphs we notice that 1040 had similar values of 200 at 1250F and 1550F but when introduced to 1400F heat treated and water quenched we received a high hardness value of 450. Material 1040 received the highest hardness value of 450 at 1400º F
  - **Yield Strength**
    - No correlation of annealing temperature to the data collected for material 1040.
  - **UTS**
    - Material 1040 at 1400º F received the highest value at 1400º F vs the other temperature phases of 1250º F and 1550º F.
  - **Modulus of Elasticity**
    - No correlation of the modulus of elasticity with anneal temperature
- **1090**
  - **Hardness**
    - Material 1090 results obtained were not expected. This could be due to human error and the 1400º F sample could show skewed results because of failure to quench fast enough for the creation of austenite. If the 1400 º F obtained a value of at least 250 to 300 range then the data would show an increasing trend of hardness. Material 1090 received the highest hardness value of 255 at 1250º F and even at 1550º F with a value of 390.
  - **Yield Strength**

        - Material 1090 experienced the highest yield strength value of about 138 at 1550º F.
    - **UTS**
        - Material 1090 experienced similar UTS values at 1250º F, 1400º F, and 1550º F. 1550º F obtained a value slightly higher than 1250º F and 1400º F but not significant vs the other metals UTS data collection.
    - **Modulus of Elasticity**
        - No correlation of the modulus of elasticity with anneal temperature
- **4140: Annealing temperature 1450º F and 1550º F**
    - **Hardness**
        - Material 4140 annealing temperature occurs at 1450 to 1550º F thus we see a difference in hardness at 1550º F water quenched giving a higher hardness value vs all the other phases that occurred in lab.
    - **Yield Strength**
        - Material 4140 at the state of 1550º F received a value of 64 which is very similar to the value at 1250º F of 62.
    - **UTS**
        - Material 4140 experienced a trend similar to material 1018.
    - **Modulus of Elasticity**
        - No correlation of the modulus of elasticity with anneal temperature