5.66 5.72 - 5.48 = 2.70mm

60 - 3.72 5.45 - 5.20 = 2.50mm

= 2.80m

LAB NO 3
HARDNESSES BY QUENCHING AND ANNEALING PROCESSES

13590

Lab 4 Heat Treatment of Carbon Steel

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Purpose: To compare the high hardness produced by quenching medium carbon steel (austenite) to the low hardness produced by annealing medium carbon steel (austenite).

Theory:

quenching: cooling rapidly.

annealing: a heat treatment whereby a previously cold-work metal is softened by allowing it to recrystallize.

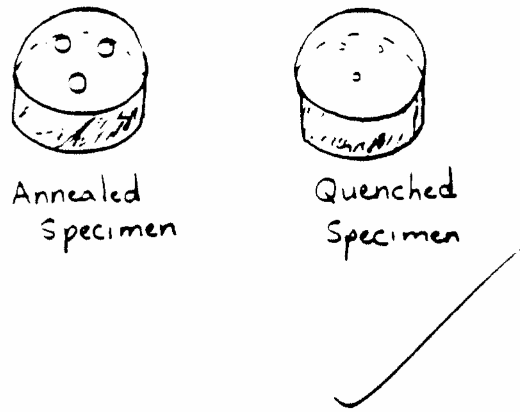
austenite: face-centered cubic iron; also iron and steel alloys that have the FCC crystal structure (stable form).

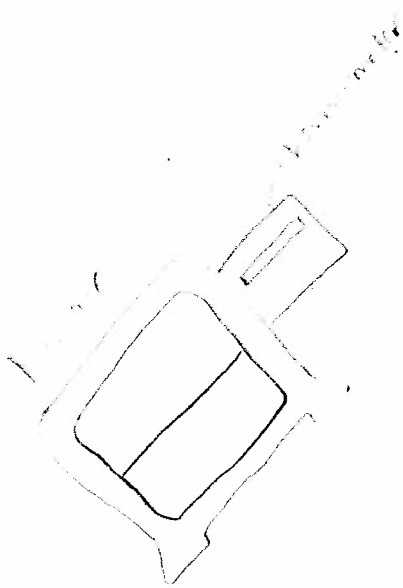
austenitizing: forming austenite by heating a ferrous alloy above its upper critical temperature to within the austenite phase region from the phase diagram

✓

hardness: the measure of a material's resistance to deformation by surface indentation or by abrasion

Fig 1 Two Coupon specimens of medium carbon steel (after Brinell hardness test)





Apparatus: Brinell hardness tester, Stopwatch
Traveling microscope, Water grinder
Magnifying glass, Furnace
Two medium carbon steel, cylindrical coupons (1045 steel

Procedure:

1. Placed one coupon in a furnace for one hour at 850°C.

2. Polished the other coupon (annealed specimen), with a water grinder, on both sides until there was a shiny appearance and all scale was removed.

(Note: Used ASTM E10-73 "Brinell Hardness of Metallic Materials")

3. Placed annealed coupon in Brinell hardness tester so that the indenter was approximately 2 times the diameter of the indentation away from the edge of the coupon and at the same time centred perpendicular from the edge. Applied a load of 1500 kgf (3000 Ps) (≈ 22,000 kpa) for ~~20 s~~ 15 s and then released the load.

4 Repeated step 3. two more times by rotating the coupon until the indentations had created a triangle that was 2 times the indentation away from the edge at the vertices, while at the same time, each indentations was approximately 2 times the indentation away from each other.

- 5.95

5 Used the traveling microscope to measure the diameters of each indentation.

6. Removed the second coupon from the furnace and quenched it in oil until it was cool

7. Repeated steps 2.-5. using the quenched coupon.

1 (2)

5.63 - 5.295 = .330 cm

2 (1)

5.615 - 5.295 = .320 cm

3 (3)

5.95 - 5.615 = .335

Results:

Table 1:

Annealed Specimen

	Diameter (mm)	Average (mm)
1st Indentation	3.27 3.28	3.28
2nd Indentation	3.27 3.25	3.26
3rd Indentation	3.30 3.30	3.30

12.92

12.63

1203

11.90

13

63

3.2

4.

Table 2

Quenched Specimen

	Diameter (mm)	Average (mm)
1st Indentation	2.75 2.75	2.75
2nd Indentation	2.68 2.70	2.69
3rd Indentation	2.65 2.65	2.65

<u>Uncertainties:</u>

[redacted] Table 3: Estimated uncertainties

Parameters	ΔP	ΔD	Δd	Δt
Instrument	± 2%	± 0.005 mm	± 0.01 mm	± 0.01 s
Object	———	± 0.010 mm	± 0.01 mm	
Use	± 5%	± 0.010 mm	± 0.01 mm	———
Total	± 5%	± 0.010 mm	± 0.01 mm	± 2.00 s
				± 2.00 s

Calculations:

$$HB = 2P / \pi D (D - \sqrt{D^2 - d^2})$$ {Notation: # HB D/P/t}

where HB is the Brinell hardness
P is the applied load, kgf
D is the diameter of the ball (indenter)
d is the mean diameter of the impression

Table 4: Hardness values for the annealed specimen.

	P (kgf)	D (mm)	d (mm)	HB (hardness)
1st indentation	1500	10	3.28	173 HB 10/1500/20
2nd indentation	1500	10	3.26	175 HB 10/1500/20
3rd indentation	1500	10	3.30	170 HB 10/1500/20
			Average :	173 HB 10/1500/20

1st indentation; $HB = 2(1500) / \pi (10)(10 - \sqrt{(10)^2 - (3.28)^2}) = 173$
2nd indentation; $HB = 2(1500) / \pi (10)(10 - \sqrt{(10)^2 - (3.26)^2}) = 175$
3rd indentation; $HB = 2(1500) / \pi (10)(10 - \sqrt{(10)^2 - (3.30)^2}) = 170$
Avg. = 173

Table 5: Hardness values for the quenched specimen.

	P (kgf)	D (mm)	d (mm)	HB {hardness}
1st indentation	1500	10	2.75	248 HB 10/1500/20
2nd indentation	1500	10	2.69	259 HB 10/1500/20
3rd indentation	1500	10	2.65	267 HB 10/1500/20
			Average :	258 HB 10/1500/20

95.54

1st indentation; $HB = 2(1500)/\pi(10)(10-\sqrt{(10)^2-(2.75)^2}) = 248$

2nd indentation; $HB = 2(1500)/\pi(10)(10-\sqrt{(10)^2-(2.69)^2}) = 259$

3rd indentation, $HB = 2(1500)/\pi(10)(10-\sqrt{(10)^2-(2.65)^2}) = 267$

Avg. = 258

[redacted]

Error Calculations

$$\frac{\Delta HB}{HB} = \frac{\Delta P}{P} + \frac{\Delta D}{D} + \frac{\Delta d}{d}$$

For annealed specimen;

1st indentation; $\frac{\Delta HB}{HB} = \frac{(0.05)(1500\ kgf)}{(1500\ kgf)} + \frac{(0.010\ mm)}{(10\ mm)} + \frac{(0.01\ mm)}{(3.28\ mm)}$

$$\Delta HB = (0.054)(173) = \pm 9.3$$

2nd indentation; $\frac{\Delta HB}{HB} = (0.05) + (0.001) + \frac{(0.01\ mm)}{(3.26\ mm)}$

$$\Delta HB = (0.054)(175) = \pm 9.4$$

3rd indentation; $\frac{\Delta HB}{HB} = (0.05) + (0.001) + \frac{(0.01\ mm)}{(3.30\ mm)}$

$\Delta HB =$ [redacted] $(0.054)(170) = \pm$ [illegible]

Average of indentations (assuming greatest error); $\Delta HB = \pm 9.4$

For quenched specimen;

1st indentation, $\frac{\Delta HB}{HB} = (0.05) + (0.001) + \frac{(0.01mm)}{(2.75mm)}$

$$\Delta HB = (0.055)(248) = \pm 14$$

2nd indentation; $\frac{\Delta HB}{HB} = (0.05) + (0.001) + \frac{(0.01mm)}{(2.69mm)}$

$$\Delta HB = (0.055)(259) = \pm 14$$

3rd indentation; $\frac{\Delta HB}{HB} = (0.05) + (0.001) + \frac{(0.01mm)}{(2.65mm)}$

$$\Delta HB = (0.055)(267) = \pm 15$$

Average of indentations; $\Delta HB = \pm 15$ (assuming greatest error).

Discussion of Uncertainties:

Instrument Uncertainties:

The instrument errors are uncertainties caused by limitations in the calibration of the instruments used in this experiment, such as the Brinell hardness tester, the stopwatch, and the travelling microscope.

Object Uncertainties:

The diameters of the indentations produced by the Brinell hardness tester may not have been completely uniform.

Use Uncertainties

The use errors in this experiment may have been caused by the following:

- not applying the correct amount of load.
- not starting and stopping the stopwatch at the exact times.
- not lining up the travelling microscope over the indentations properly.
- making the indentations too close to one another or too close to the edge of the coupons.

All of these factors will affect the hardness measurements

Conclusion:

Table 6: Hardness values for the annealed and quenched specimens

Specimen	Hardness	Error in Hardness
Annealed	173 HB 10/1500/20	± 9.4
Quenched	258 HB 10/1500/20	± 15

Thus, it can be concluded that quenching (cooling rapidly) medium carbon steel from the austenitic temperature range (≈ 850 °C) produces a very high hardness when compared with the lower hardness that annealing (cooling slowly) medium carbon steel from the austenitic temperature range produces.