HCM University of Technology

Materials and Heat Treatment

ME2015

Lab Report

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Chapter 1

HARDNESS TESTING OF METALS

1.1 Experimental targets

- Understand the principle of Brinell, Rockwell and Vicker hardness measurement methods.
- Familiar and pracce the common hardness equipment.

1.2 Theoretical summary

Hardness tests are performed more frequently than any other mechanical test for several reasons: They are simple and inexpensive-typically, no special specimen need be prepared, and the testing apparatus is relatively inexpensive. The test is non-destructive —the specimen is neither fractured nor excessively deformed; a small indentation is the only deformation. Other mechanical properties often may be estimated from hardness data, such as tensile strength.

1.2.1 Brinell Hardness Test

A hard, spherical indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel (or tungsten carbide) indenter is 10.00 mm (0.394 in.). Standard loads range between 500 and 3000 kg in 500-kg increments; during a test, the load is maintained constant for a specified me (between 10 and 30 s). Harder materials require greater applied loads. The Brinell hardness number, HB, is a function of both the magnitude of the load and the diameter of the resulting indentation . This diameter is measured with a special low-power microscope, utilizing a scale that is etched on the eyepiece. The measured diameter is then converted to the appropriate HB number using a chart; only one scale is employed with this technique.

1.2.2 Rockwell Hardness Tests

Indenters include spherical and hardened steel balls having diameters of 1/16, 1/8, ¼, and 12 in. (1.588, 3.175, 6.350, and 12.70 mm, respectively), as well as a conical diamond (Brale) indenter, which is used for the hardest materials. With this system, a hardness number is determined by the difference in depth of penetration resulting from the application of an initial minor load followed by a larger major load; utilization of a minor load enhances test accuracy. On the basis of the magnitude of both major and minor loads, there are two types of tests: Rockwell and superficial Rockwell. For the Rockwell test, the minor load is 10 kg, whereas major loads are 60, 100, and 150 kg. When specifying Rockwell and superficial hardnesses, both hardness number and scale symbol must be indicated. The scale is designated by the symbol HR followed by the appropriate scale identification.

1.2.3 Knoop and Vickers Microindentation Hardness Tests

Use a very small diamond indenter having pyramidal geometry is forced into the surface of the specimen. Applied loads are much smaller than for the Rockwell and Brinell tests, ranging between 1 and 1000 g. The resulting impression is observed under a microscope and measured; this measurement is then converted into a hardness number. The Knoop and Vickers hardness numbers are designated by HK and HV, respectively, and hardness scales for both techniques are approximately equivalent. Both are well suited for measuring the hardness of small, selected specimen regions; furthermore, the Knoop technique is used for testing brittle materials such as ceramics.

1.2.4 Hardness Conversion

Have been determined experimentally and found to be dependent on material type and characteristics. The most reliable conversion data exist for steels, some of which are presented in Figure 1.4 for Knoop, Brinell, and two Rockwell scales; the Mohs scale is also included. Detailed conversion tables for various other metals and alloys are contained in ASTM Standard E140, “Standard Hardness Conversion Tables for Metals”. In light of the preceding discussion, care should be exercised in the extrapolation of conversion data from one alloy system to another.

1.3 Detailed Experiment

1.3.1 Measure HR

Put sample on the flat form of the equipment (anvil). Setting force application, Rockwell indentor conditions (HRA, HRB, HRC). Rotate clockwise the control to

lift the flat form of the equipment until the sample touches the indentor. Continue rotating the control until the short hand rotates the red position. Rotating the watch face so that the long hand points at C-B position . Press start button, waiting in 10s (duration of applying force). After 10s, a “beep” sound is released. The position of the long hand shows the measured value. Notice that, the black outside cycle is HRA, HRC and the red inside cycle indicates HRB. Rounding values to 0.5. - Rotate counterclockwise the control to release the sample and repeat the measurement for other 2 mes (3 measured points are close to avoid the error due to uneven hardness.

1.3.2 Measure HB or HV

Put sample on the flat form of the equipment. Rotate clockwise the control to li the flat form of the equipment until the sample touches the indentor. Continue rotating the control until the needle moves to the end of the ruler. Lower gently the force control bar to the end of the range and wait for 10 seconds then lifting up the force control bar lightly. - Rotate clockwise the control to release the sample. Mark on the measured dimple by the pen. This process was repeated other 2 mes. - Take one of the three holes to measure diagonal length D (for HV method) or the concave diameter D (for HB method) by using optical measurement. The other two holes will be measured on the microscope and the data will be upload on the web page of the Material Processing Department. Then, students download data and complete the report.

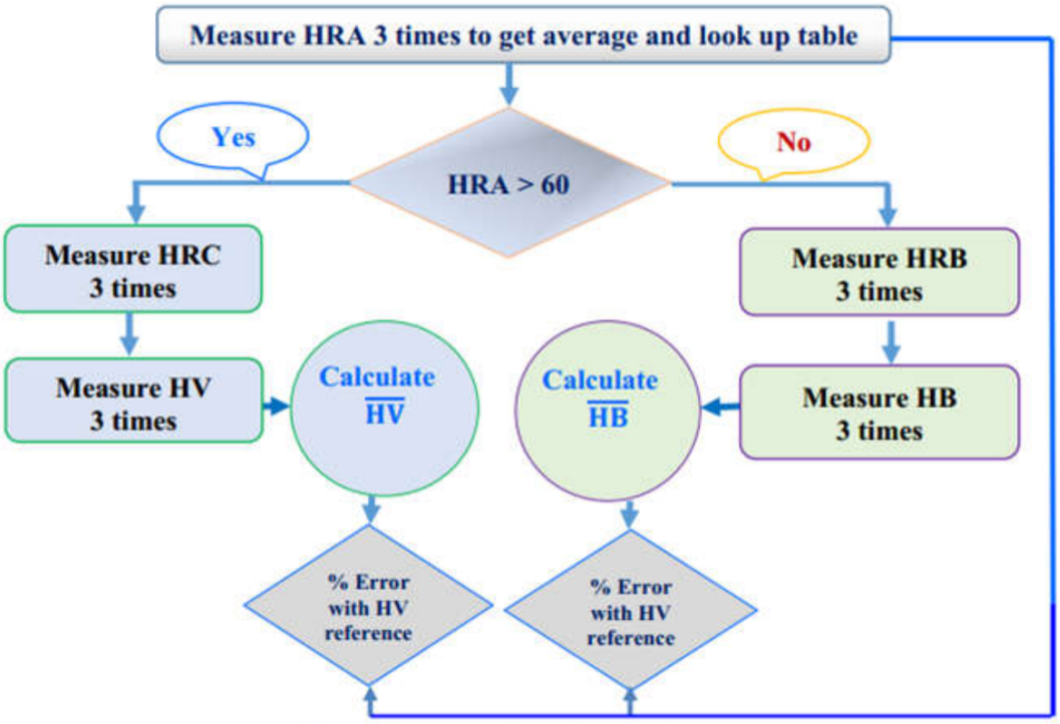

Figure 1.1: Measured practice procedure

1.4 Measurement results

Properties		1^{st} measure	2^{nd} measure	3^{rd} measure	Avg
HRA		-	-	-	-
HRB/HRC		106/27	106/30	103/27	105/28
HV/HB	Diagonal line	HOLE 1	HOLE 2	HOLE 3	-
	D_1	0.846	0.833	0.815	-
	D_2	0.872	0.859	0.841	-
	Avg	0.859	0.846	0.828	-

Table 1.1: Measurement results

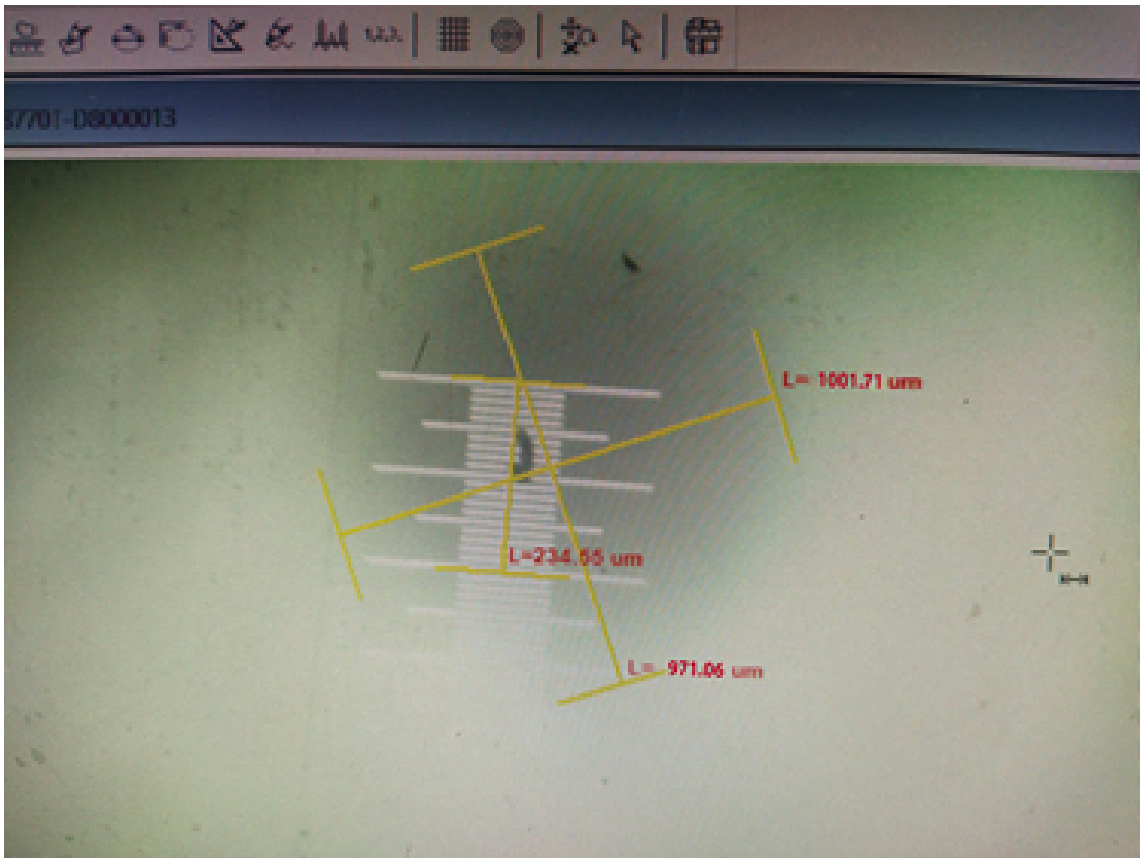

Figure 1.2: Experimental results of the diagonal lines

1.5 Analyzing results

Lookup table We look up the table according to the website:

https://www.steelexpress.co.uk/steel-hardness-conversion.html

Steel Hardness conversion calculator

Brinell Hardness HB	Rockwell C - HRC	Rockwell B - HRB	Vickers - HV	
264	28	103	271	Calculate

Enter a figure into any of the fields and click calculate, the nearest values in each scale is shown, or zero if out of range. Values are approximate and for guidance only.

Figure 1.3: Lookup table

$\Rightarrow HV_{theory} = 271$

Calculate average HV The results are as follows (Let $P = 980$ (N)):

$$HV_1 = \frac{2P \sin\left(\frac{136^\circ}{2}\right)}{9.81\overline{D}_1^2} = 251.1$$

$$HV_2 = \frac{2P \sin\left(\frac{136^\circ}{2}\right)}{9.81\overline{D}_2^2 2} = 258.8$$

$$HV_3 = \frac{2P \sin\left(\frac{136^\circ}{2}\right)}{9.81\overline{D}_3^2} = 270.2$$

$$\overline{HV} = \frac{HV_1 + HV_2 + HV_3}{3} = 260$$

$$\delta = \frac{|HV_{theory} - \overline{HV}|}{HV_{theory}} \times 100\% = 4.06\%$$

1.6 Conclusion

Based on experimental data, the error between reality and theory when measuring the HRC hardness of the sample is very small, only about 4.06% and when measuring HV hardness, the error between reality and theory is also very small (4.06%) and negligible

Explanaon about errors

- Due to laboratory equipment, machines and instruments, the integrity of the prick, the load of the machine, the inclination of the work piece surface, the error of the indicator.
- Due to the measurer's estimation of the indicator data on the meter.
- Due to rounding.
- Because the surface of the sample has not been carefully grounded.
- Because the placement of the prick is not reasonable.
- Due to the uneven holding me between measurements.
- Due to the meter calibration is not good.

- Due to the inaccurate determination of line d, it causes errors in HV hardness.
- Due to the lifting of the booms, the rhythm of the measuring hole is not smooth.

Chapter 2

MICROSTRUCTURE ANALYSIS IN METALLIC MATERIALS

2.1 Experimental targets

- To Learn the preparation of specimen for microscopic observation.
- To understand what microscopy is, and how it can be used to observe Microstructure of metals.

2.2 Theoretical summary

- **Metallography:** Is the study of metals by optical and electron microscopes.
- **Optical microscopy**: With optical microscopy, the light microscope is used to study the microstructure; optical illumination systems are its basic elements.

- **Sectioning:** Operations such as shearing produce severe cold work, which can alter the microstructure of a sample.
- **Mounting:** Small samples are generally mounted in plastic for convenience in handling and to protect the edges of the specimen being prepared.
- **Coarse Grinding**: The purpose of the coarse grinding stage is to generate the initially flat surface necessary for the subsequent grinding and polishing steps. Course grinding can be accomplished either wet or dry using 80 to 180 grit electrically powered disks or belts, but care must be taken to avoid significant heating of the sample.
- **Medium and Fine Grinding:** To produce a scratch free surface by employing a series of successively finer abrasives.
- **Mechanical Polishing:** Polishing involves the use of abrasives, suspended in a water solution, on a cloth-covered electrically powered wheel.
- **Etching:** Microscopic examination of a properly polished, unetched specimen will reveal only a few structural features such as inclusions and cracks or other physical imperfections. Etching is used to highlight, and sometimes identify, microstructural features or phases present.

2.3 Detailed experiment

- Cut out the work piece.
- Coarse grinding: Use sand paper from small to big number (80,100,150,180,400).
- Polishing: Use polishing machine attached by cloth soaked in water.
- Get the surface image from the microscope.
- Etching: Use acid to remove the outer layer of the surface, then clean the

surface with water.

- Get the surface image again from the microscope.

2.4 Microstructure before and after etching

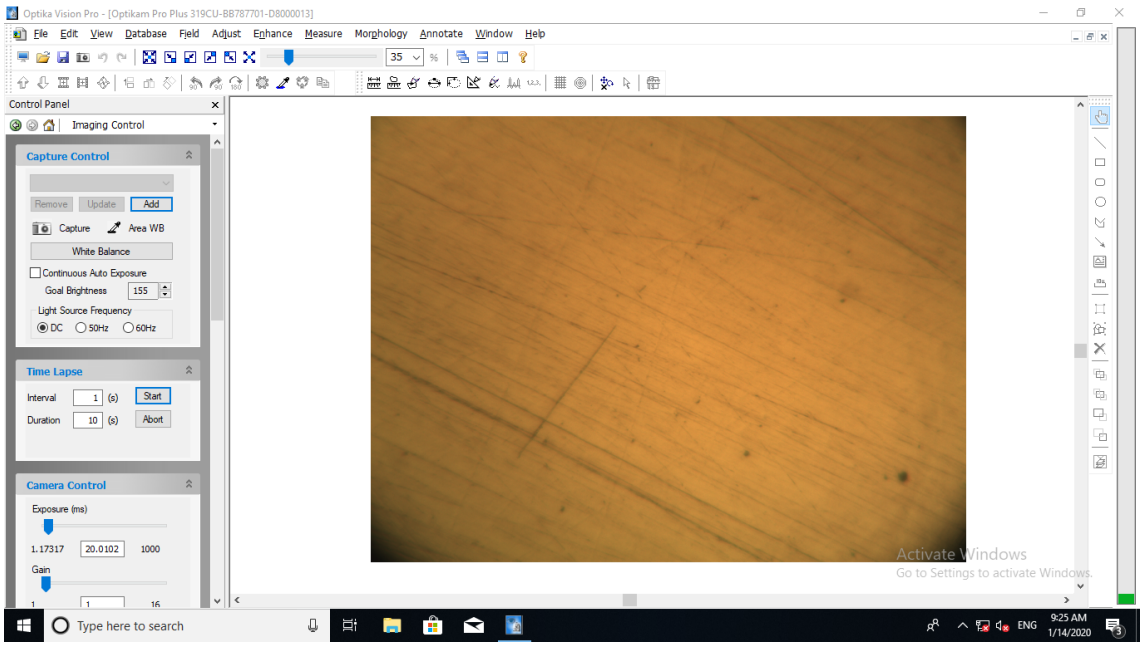

Figure 2.1: Microstructure of the sample before etching

2.5 Conclusion

Before food etching:

- The pre-impregnated sample is very bright with the naked eye due to careful polishing. However, the scratches are still visible and crossing each other under the microscope.
- In conclusion, the process of sanding and polishing are guaranteed to reduce the scratches. However, abusing this process too much will peel off the hardened surface of the sample, which makes it prone to environmental damages.

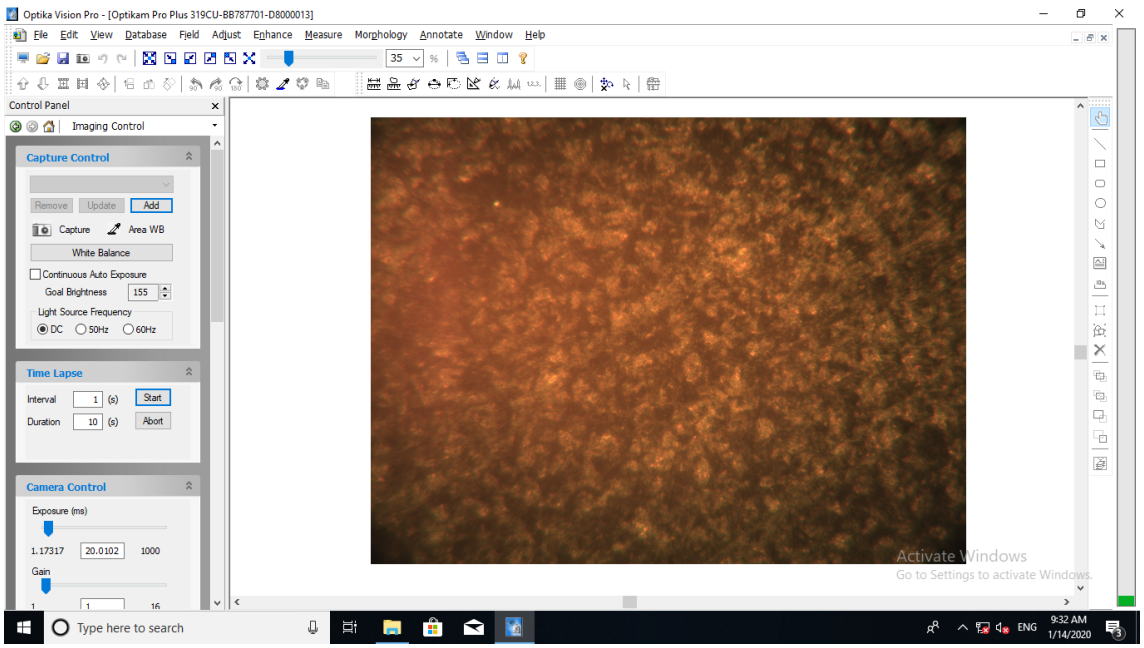

Figure 2.2: Microstructure of the sample after etching

After food etching:

- After impregnation, the surface becomes blur because of porous at microscopic scale, which is evident by black spots on the images above. If the sample is exposed to air, the surface will become darker.
- The reaction of the sample surface with the etching solution is not the same at all points.
- The more polished the sample is, the easier it is to see the results after impregnating it, then it is easy to see the border between particles and phases together through a microscope.
- The more impregnated at the required time, the more visible the results will be because the grain and phase boundaries have not been corroded too much.

In summary:

- The given sample has different phases lying alternately so that the reactions

are not homogeneous on the sample surface.

- When etching the phases on the sample, it is unevenly corroded or there are some phases that are corroded faster, the irregular corrosion creates a rough surface for the sample (surface roughness).
- The given sample has soft and hard phases interspersed together to form a uniform mass.
- The boundaries between the phases and the particles are quite even, with no major defects.

Chapter 3

QUENCHING PROCESS

3.1 Experimental targets

- Understand the quenching process: chosing heang temperature, heang me and cooling environment.
- Study the relaonship between quenching temperature, colling rate, and hardness of steel.

3.2 Theoretical summary

Tempering is done to develop the required combination of hardness, strength, and toughness or to relieve the brittleness of fully hardened steels. Tempering is the process of reheating the steel at a relatively low temperature leading to precipitation and spheroidization of the carbides present in the microstructure. The tempering temperature and mes are generally controlled to produce the final properties required of the steel. The result is a component with the appropriate combination of hardness, strength, and toughness for the intended application. Tempering is also effective in relieving the stresses induced by quenching.

Low tempering Ranging from 150°C - 250°C

The microscopic structure after the process is called mactencite, the work piece hardness change a little, and receive erosion resistance.

Low tempering Ranging from 300°C – 450°C

After the process the hardness of the work piece is high (40-45HRC), stress is lowered by a bit, increase elasticity, yield strength increase to maximum value.

Low tempering Ranging from 500°C – 650°C

3.3 Detailed experiment

- 3 samples are quenched in water and then low tempered at 250°C for about 20 minutes
- 3 samples are quenched in oil.

3.4 Measurement results

Hardness type	Sample 1 (HRC)				Sample 2 (HRC)				Sample 3 (HRC)			
No	1	2	3	Avg	4	5	6	Avg	7	8	9	Avg
Before tempering	10.63	10.63	10.20	10.49	10.90	9.23	11.57	10.57	10.33	9.93	9.70	9.99
Water	58.50	60.00	60.00	59.50	60.50	59.00	60.30	59.93	57.50	58.00	59.50	58.33
Oil	54.00	54.00	51.00	53.00	54.00	54.00	50.00	52.67	53.80	52.50	50.00	52.10
Air	14.00	16.00	17.00	15.67	17.00	18.80	19.00	18.27	15.00	14.80	16.00	15.27
High tempering (550°C)	36.20	35.20	35.50	35.63	36.10	36.00	36.00	36.03	35.80	36.80	36.90	36.50
Low tempering (150°C)	55.20	57.00	58.00	56.73	54.40	56.30	55.80	55.50	55.00	55.30	54.30	54.87

Table 3.1: Measurement results

3.5 Relationship

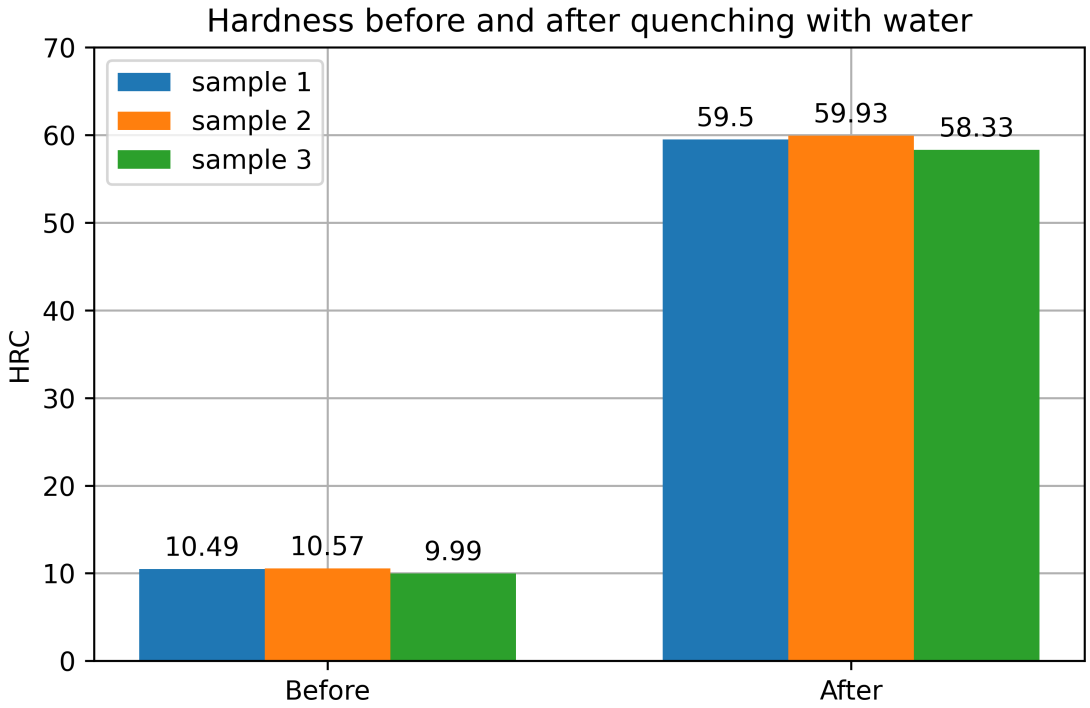

Figure 3.1: The relationship of hardness between before and after quenching

3.6 Conclusion

- After tempering, the hardness of the sample in the experiment increased. The hardness of the sample increases gradually as it cools in the environment in the order of air, oil, and water. At the same heating temperature and incubation time and furnace when cooled at different field conditions, the samples received have different hardness (increase or decrease).
- Test samples after quenching at high temperatures have lower hardness than when quenching at low temperatures.
- After quenching the sample has been tempered, the hardness of the sample decreases, but depends on the quenching temperature and required hardness after quenching.

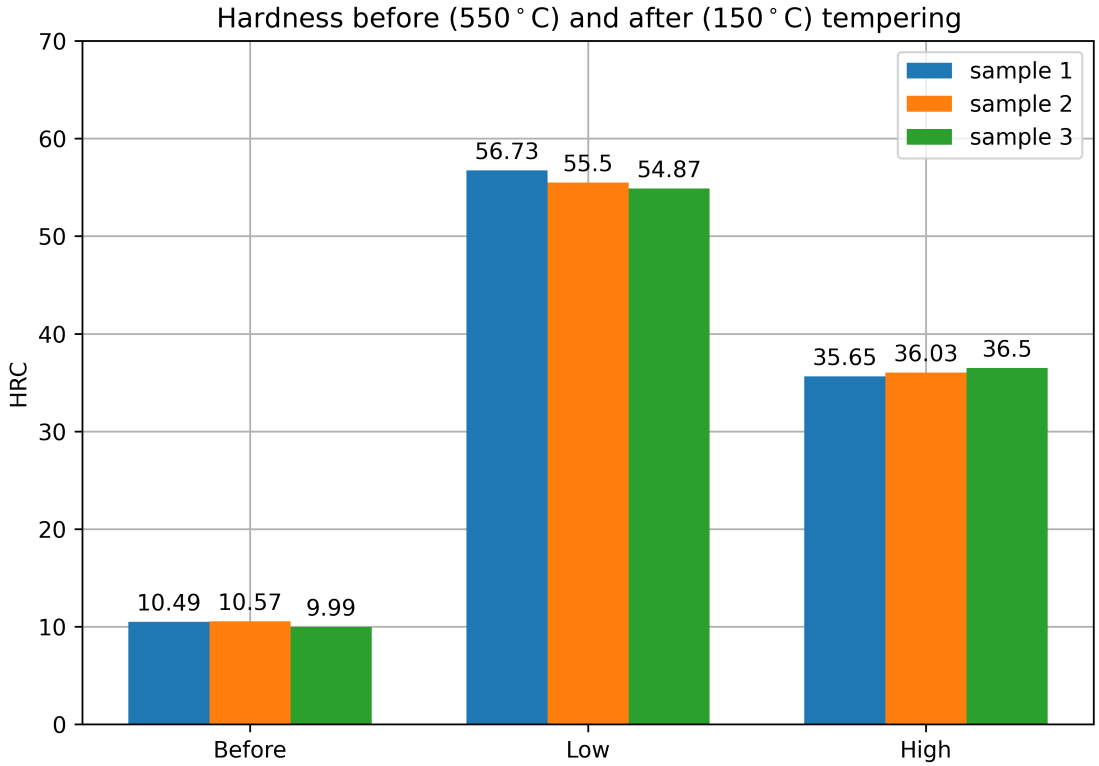

Figure 3.2: The relationship of hardness after tempering

- After quenching the sample has been tempered, the hardness of the sample decreases, but depends on the quenching temperature and required hardness after quenching.