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CHARACTERIZATION OF ROCKWELL HADNESS TESTING MACHINE USING INDENTER SAMPLES WITH LOAD

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Abstract

Hardness is a measure of the resistance of a material to be penetrated and eroded by sharp projections of other materials such as diamond. The process of creating sharp projections on any test surface is known as indentation. Hardness measurement of any material is the result of a complex process of deformation during indentation. The indenter tip geometry, which includes radius of curvature at the tip and tip angle, affects the hardness measurement by influencing the nature of the penetration process on the test surface, because every indenter deforms the specimen surface with a different geometry. The controlled indenter geometry can improve the consistency of hardness measurement. In this paper we report the estimation of two important geometrical parameters, radius of curvature and tip angle of a Rockwell indenter by using a simple method of image processing and compare the results with those obtained with a traceable 3D optical profiler. Evaluation of uncertainty in measurements is carried out as per ISO guidelines (ISO-GUM) and a detailed uncertainty budget is presented. The tip angle estimated is 119.95 degree. The radius of curvature is estimated to be 199.96 ± 0.80μm by image analysis which agrees well with the value estimated by using optical profiler i.e. 199.12 μm.

Keywords: ***Indenter, radius as curvature, tip radius, image analysis, uncertainty***

Introduction

Hardness can be defined as the resistance of material to local plastic deformation on the application of some external load or stress (scratch, indentation or abrasion). Although hardness is not a fundamental property of material, hardness testing is widely used in industries because of its simplicity, faster results, near NDT testing properties, cheap procedure and many more advantages. Also, it can give a qualitative relationship to other materials properties like strength, ductility, rigidity etc. Indentation testis one of the prominently used hardness testing method where we apply a certain predefined load with the help of an indenter which penetrates into the sample surface; thus we get the hardness values by measuring the indentation depth or size of the projected indentation area.

Rockwell hardness test is one of the static hardness testing methods using indentation depths measuring criterion. Basically, two types of indenter are used; one Diamond Sphere conical (Bralle) indenter with an angle of 120^{O} and as spherical tip of 0.2mm; second is steel ball indenter with diameters as 1/16, 1/8, 1/4, ½ inches. Rockwell Test works on the principle of major and minor load where we first apply a minor load (10kg for regular test and 3kg for superficial tests) to the sample that minimizes the surface preparation and minor defects; then a major load are applied for some d well time which is removed after the dwell period and a differential depth (incremental depth) is observed. A dial is attached to the testing machine which gives the arbitrary hardness number during the whole process. To cover a different hardness range with varying penetration, the dial has different scales like A, B, C, D etc. on the basis of indenter and load used. The most general dial has Scale C&A for Brale Indenter and load 150 & 60 respectively; a B scale for steel ball (1/16 inches diameter) and 100 kg load.

Methodology

This process helps me to l understand the principles and operation of the Rockwell Hardness Testing machine. and it can perform the experiment of hardness testing in mechanical engineering lab. 1. Application 1. In Machining Industry: Check the hardness of job before doing machining of the job if it is very hard then they special type of cutting tools. 2. Mechanical Labs: Used for checking the strength and hardness of different products for quality insurance 3. Heat treatment lab: Use to check the hardness before and after hardening and annealing processes and also used to check quality of the metal before and after treatment processes. Heat treatment is a controlled process used to alter the microstructure of material ductility and toughness.
Here are the explanation of heat treatment focusing on its use to check the quality of the hardness, before and after the hardening and annealing process. This process includes preparation: (1). Preparation: the material is cleaned, and any surface imperfection is removed to ensure even heating (2). Heating: the material is heated to specific temperature, depending on the desired outcome. (3). Socking: the material is held at the elevated temperature for a period to allow the microstructure to change. (4). Cooling: the material is cooled at a controlled rate to achieve the desired properties. Hardening process, this process is heat process used to increase the hardness of the material which involves (1). Austenitization: heat material to a temperature above the critical point 843^0C for steel to form austenite. Quenching: rapidly cooling the material using a medium like water, oil or air to transform the austenite into marten site, a hard brittle macrostructure.

Results and analysis

The materials used for this experimental study was 0.3 wt. % carbon steel (low carbon) and 1.1wt.% carbon steel (high carbon) both of which were subjected to two different cooling rates after austenitization. In one case, after austenitization, the sample was subjected to furnace-cooling (annealing treatment) while in the other case, it was quenched in water. This was maintained at room temperature. Two samples having similar composition and subjected to similar heat treatment for each case were used for performing Vickers' bulk hardness test to increase the statistical reliability. Experiment is carried out with a total 10 samples and each sample is denoted with a sample code for easier understanding and this code will be followed throughout the whole report which has been shown in Table 1, with its respective composition and heat treatment.

Table 1: Steel samples with their respective composition and heat treatment.

Sample Code	Carbon Composition (wt.%)	Heat Treatment
1 **2**	0.3	Annealed
3 **4** **5** **6**	0.3	Water Quenched
7 **8**	1.1	Annealed
9 10	1.1 1.1	Water Quenched OIL Quenched

The steel samples were first grinded and were then metallographic polished up to 1500 mesh size Sic paper followed by polishing in cloth up to 2500 mesh size and was finished by polishing in 1µm diamond paste and kerosene. First of all, it is ensured that the sample Surface is smooth, flat and parallel. To the requirement, the suitable indenter (either ball or diamond) is installed. The sample is now placed on the stage. Major and minor loads are set as per requirement. Now the sample is brought in contact with the Indenter using a screw system. The screw is rotated until the bigger dial hits zero at the top and smaller dial points towards the red points (It takes around 3 rotations of the bigger dial to bring the smaller dial to point towards the red point.) Now the lever is pulled and the Machine is loaded. It takes about 15-20 seconds to apply the desired load.) The machine is now unloaded and reading is noted. A few seconds of waiting time is recommended to Ensure accurate reading. Suitable scale B scale for soft material and C scale for harder material for measurement is chosen according to the nature of the sample.

Sample materials:

1. 0.3%C Steel Water Quenched
2. 0.3%C Steel Annealed
3. 1.1%C Steel Water Quenched
4. 1.1%C Steel Annealed
5. 1.1%C Steel Oil Quenched

The following procedure was adopted for the experiment for each sample:

1. The sample was prepared for the hardness test by effective grinding and polishing (both coarse and fine).
2. Using proper etchants, the microstructure of the sample was observed.
3. The sample was placed on the working table of the micro hardness testing machine and the jaws were used to fix its position under the optical microscope.
4. The reticules of the eyepiece lens were moved to coincide with each other and indentation locations on the sample were identified approximately.
5. The turret was manually rotated to fix the indenter over the sample. The necessary force and dwelling time (depending on the phase under scrutiny) were given as inputs to the machine and indentation was allowed to occur.

Measurement of hardness test

Measurement of macro hardness of the Samples by Rock well provides us a clear picture about how the hardness of a sample increases on increasing the carbon content from 0.3wt.% to 1.1 wt. % when subjected to the same heat treatment. The experiment also showed how the hardness of the sample was dependent on the cooling rate. With an increase in the cooling rate, the sample was found to have a greater value of hardness for the same carbon content. Measured hardness value of the given sample has been shown in table2.

Table 2: Steel samples with their hardness in Rockwell B and C scale.

	Hardness
1	HRB 74
2	HRB 70
3	HRC 28
4	HRC 30
5	HRC 26
6	HRC 29
7	HRB 94
8	HRB 95
9	HRC 53
10	HRC 54

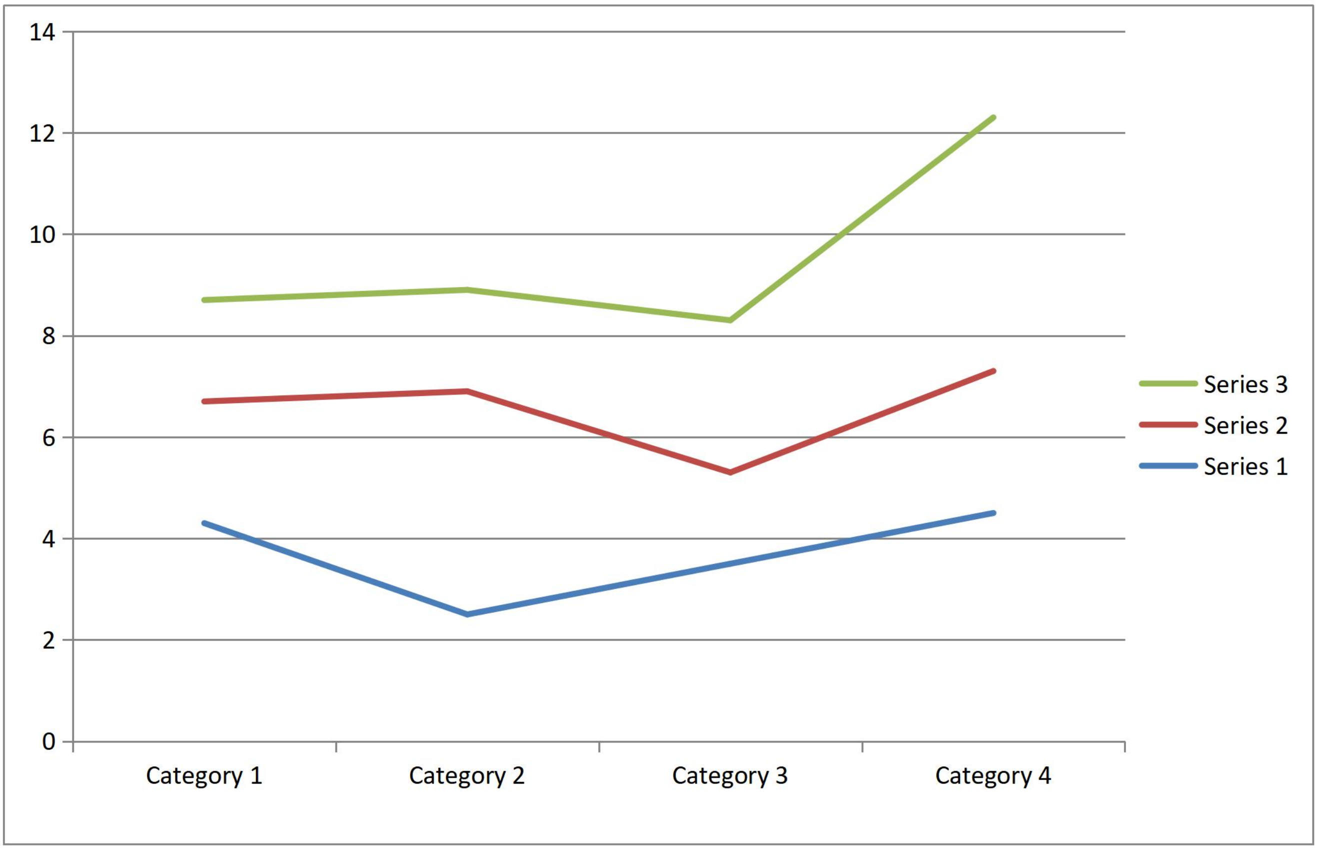


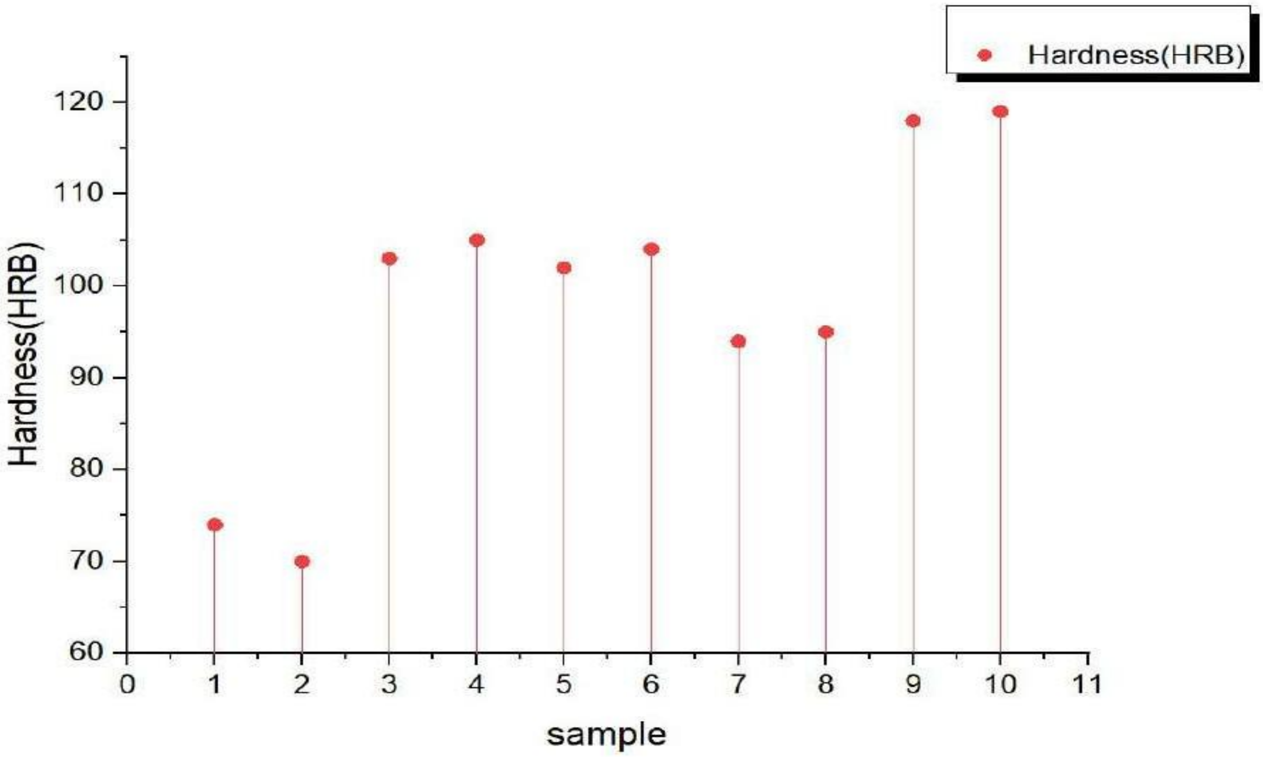
Figure 1: Graph for table 2 representation of rock well hardness testing results

From the above hardness table it can be seen that all 10 sample hardness cannot be measured with the same rock well scale. So for comparison and plotting, all hardness value is converted to Rockwell B scale [2]. Converted value of hardness to the Rockwell B scale has been shown in table3.

Table 3: Steel samples with their hardness converted to rock well B scale.

	Hardness(HRB)
1	HRB 74
2	HRB 70
3	HRB 103
4	HRB 105
5	HRB 102
6	HRB 104
7	HRB 94
8	HRB 95
9	HRB 118
10	HRB 119

Figure 2: Variation of hardness based on composition and heat treatment.

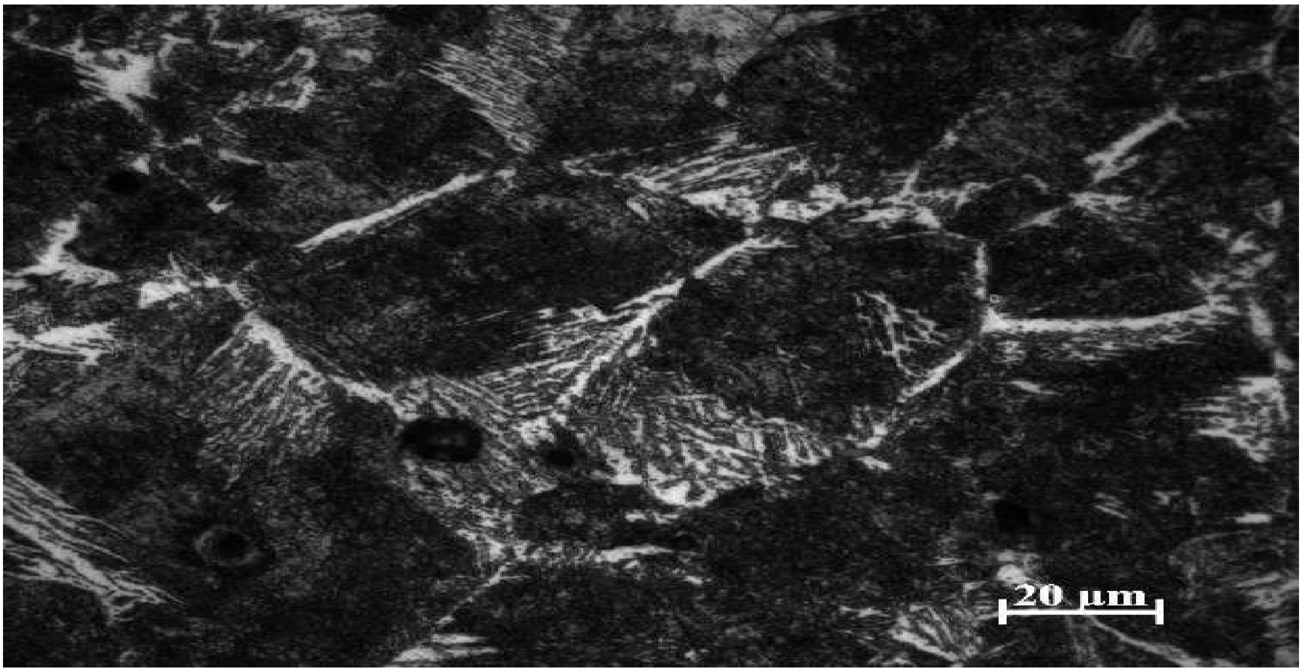


A graph which shows how hardness varies among different samples as are shown in the figure above. It can be easily in fired from the experiment that lower percent annealed carbon steel (0.3 wt. %) has low hardness because they are expected to have large and soft ferrite grain after the heat treatment and higher percent annealed carbon steel (1.1 wt. %) has more hardness because of the presence of pro eutectoid cement it along with a large amount of pearliest present in the matrix, both of which are hard phases compared to ferrite. The hardness of 0.3 wt. % water quenched carbon steel is higher than that of 0.3wt.% annealed carbon steel due to faster quenching rate which causes austenite to marten site transformation resulting in build-up of residual stress and lattice strain. Marten site which is a harder phase than ferrite or pealite and lath marten site is formed here.

ROCK WELL HARDNESS TEST UNIT

Figure 3: Rockwell Hardness Test unit

INDENTER SAMPLES WITH LOAD



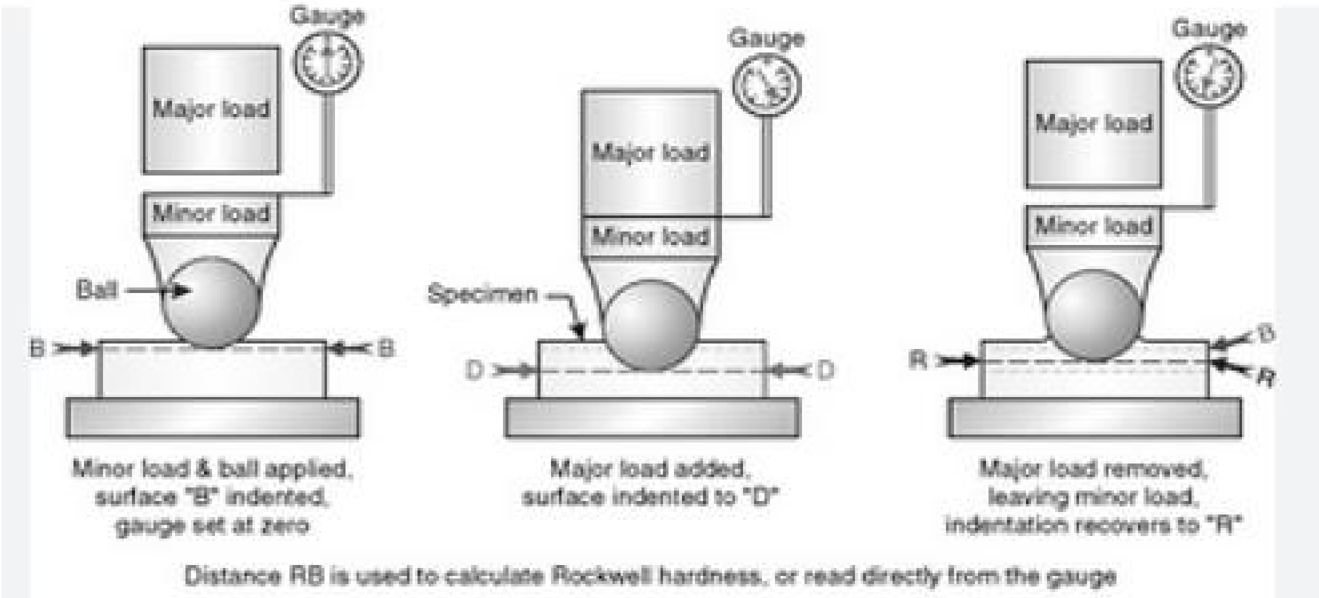


Figure 4: Indenter sample with Load

Figure 5: Micro structure of 0.3%C Steel (Water Quenched)

Highest hardness can be seen in 1.1 wt. % carbon steel water quenched because of the fact that with increase in Carbon content more lattice distortion and residual stress forms in the marten site and the Marten site which is formed is plate marten site which has a high twin density. Because of all these factors mentioned above hardness of 1.1 wt. % carbon steel water quenched sample is higher compared to the rest of the samples. The indentation images of the steel samples are shown in the figures attached above and result of Micro structures of the samples are shown below.

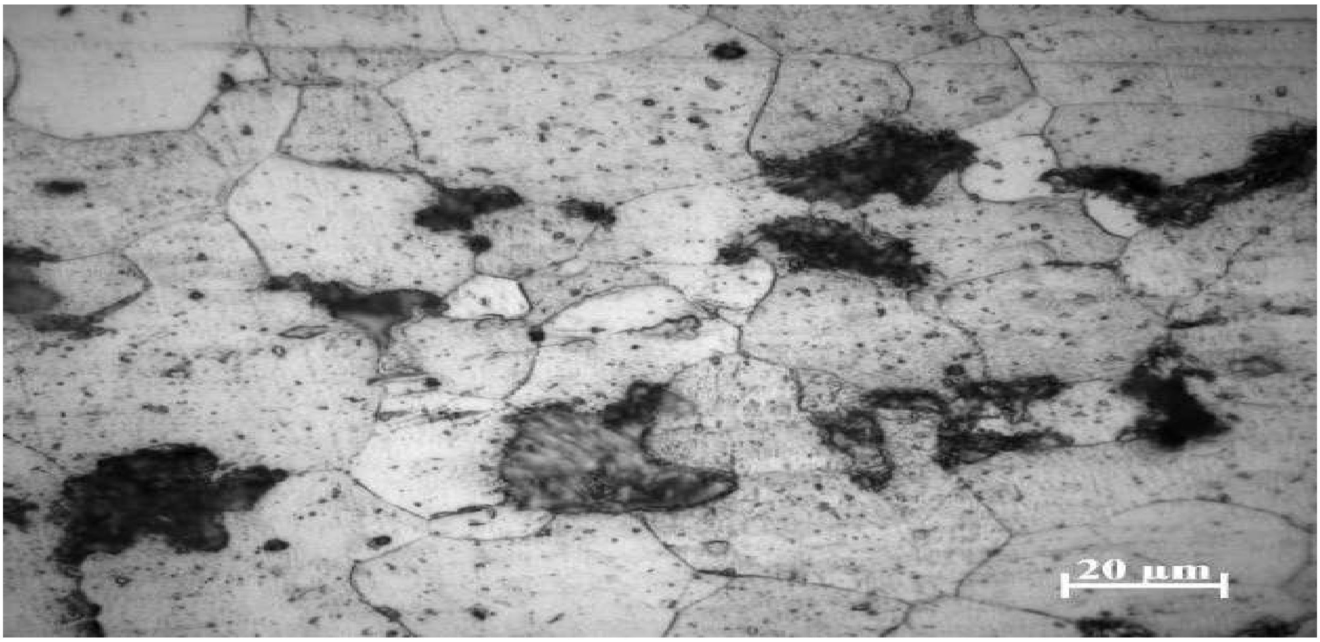


Figure 6: Micro structure of 0.3%C Steel (Annealed)

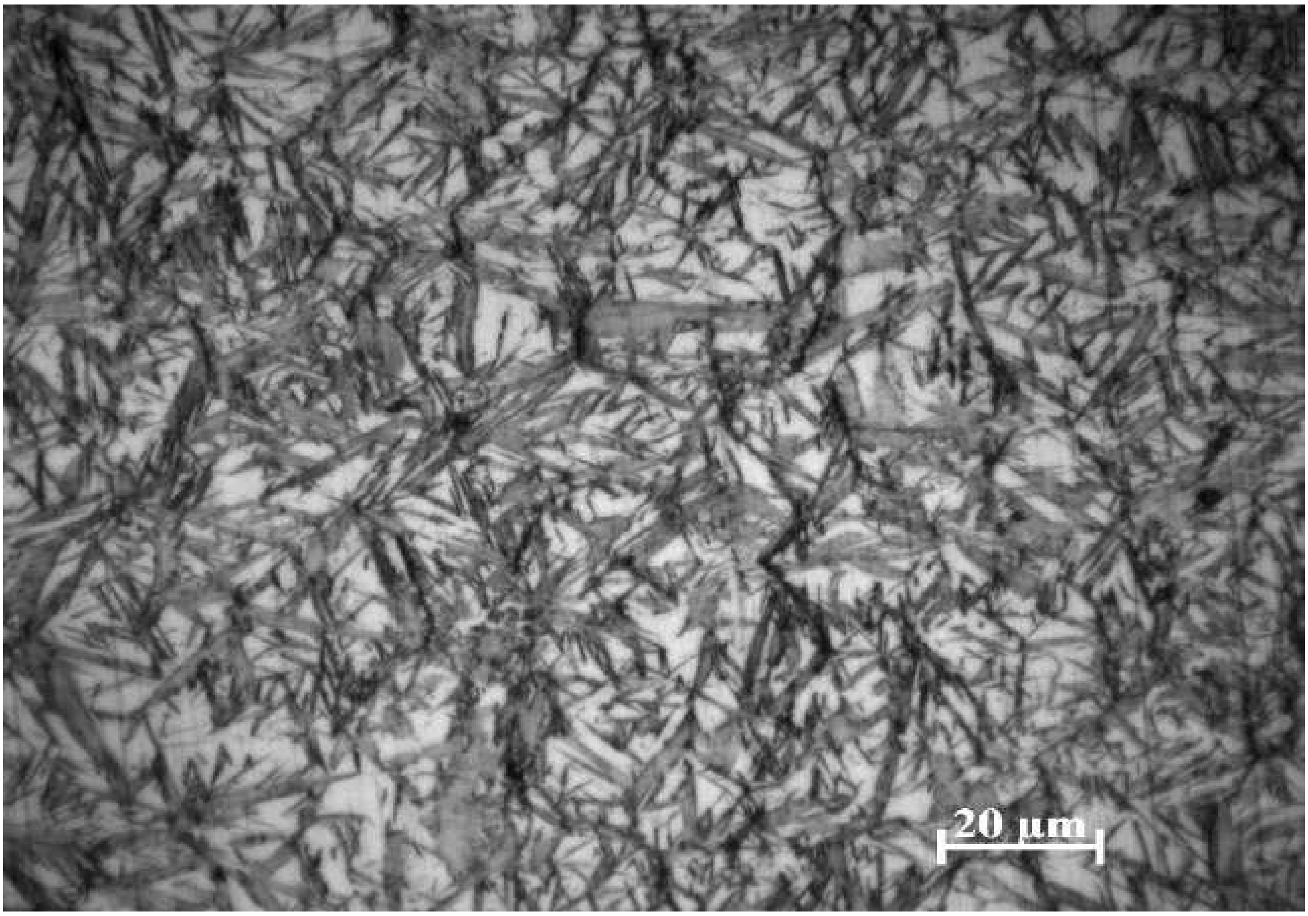


Figure 7: Micro structure of 1.1%C Steel (Water Quenched)

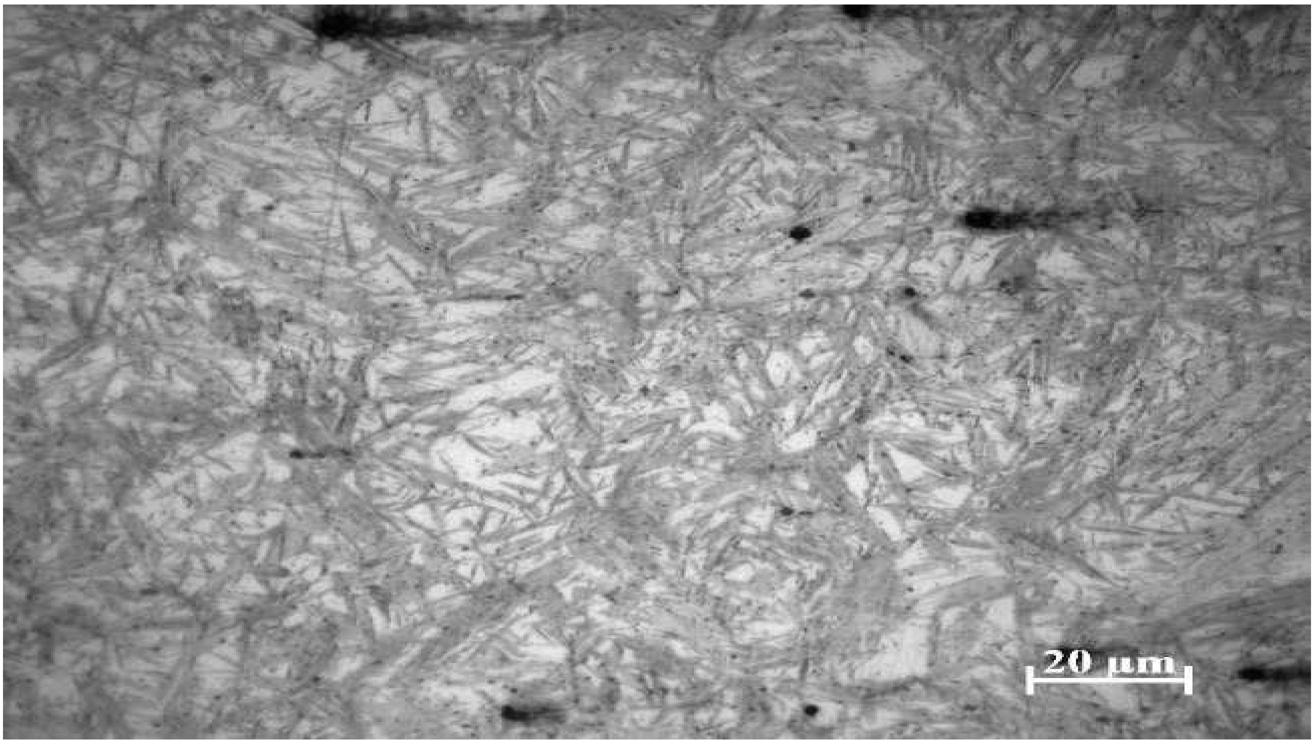


Figure 8: Microstructure of 1.1%C Steel (Oil Quenched)

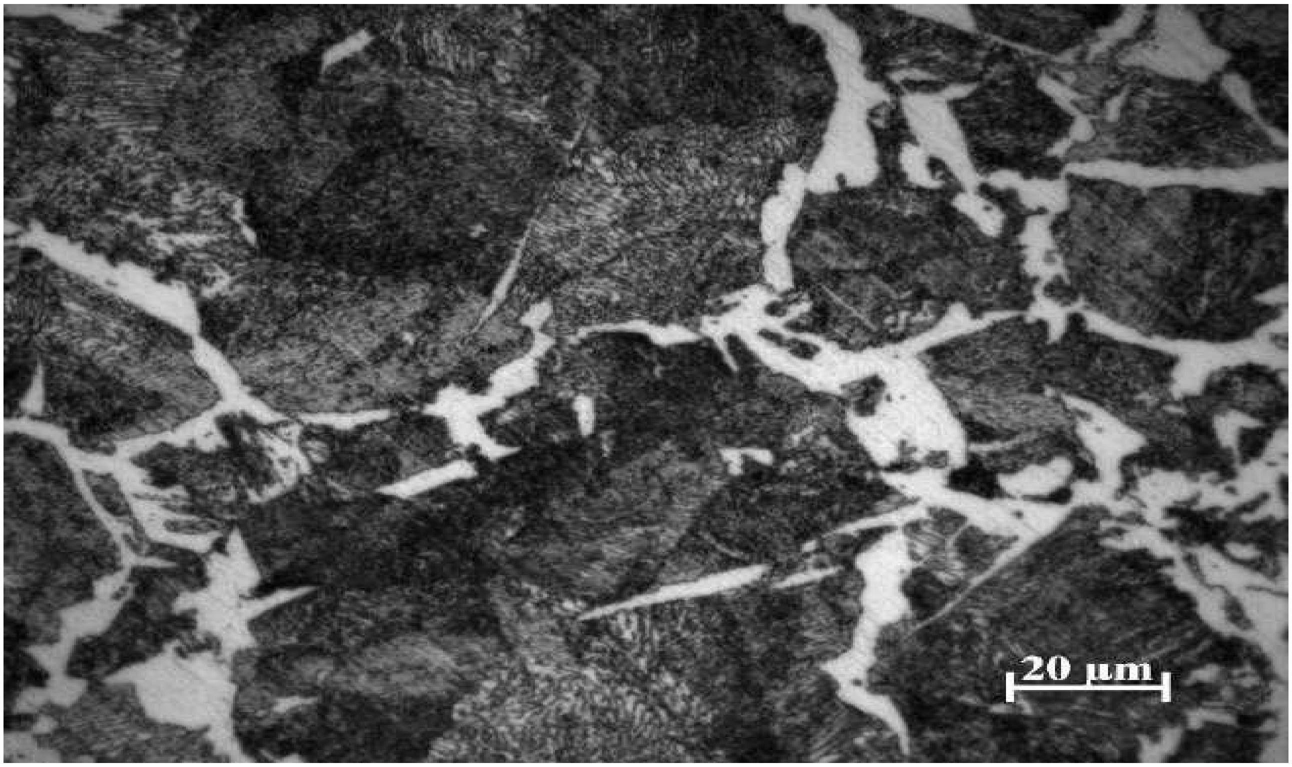


Figure 9: Micro structure of 1.1%C Steel (Anneale)

Conclusion

With the help of this experiment, we have been able to relate how hardness of steel samples is affected by variation in carbon content and the rate of cooling applied on the sample. From this experiment, we can conclude that, Rockwell hardness of a steel specimen increases with increase in the carbon content, keeping the cooling rate constant. Keeping Rockwell hardness of a steel specimen increases with increase in the cooling rate, the carbon content constant

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