MM208 Report

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Brief Introduction on Heat Treatment:-

Heat treatment is akin to providing material with a transformation. Through controlled heating followed by precise cooling, we can alter its internal composition to enhance strength, hardness, or flexibility. This method entails heating the material to a designated temperature, maintaining it for a specified duration, and then gradually cooling it. It holds immense significance as it enables the production of material components that exhibit improved performance and longevity across various machinery and tools.

Heat treatment in Mild Steels:-

Annealing, Normalizing, Austempering, Tempering, and Quenching are crucial heat treatments commonly employed to alter the microstructure and characteristics of steels. In our laboratory experiments, we primarily utilized Annealing, Normalizing, and Quenching.

Specifically, we worked with mild steel, a type of carbon steel characterized by low carbon content, typically ranging from 0.05% to 0.25% by weight. The mild steel we used in the lab contained 0.022% carbon by weight.

1) ANNEALING: ***This method entails heating the steel to a high temperature and then allowing it to cool slowly. It's akin to providing the steel with a relaxing spa treatment, relieving internal stresses and rendering it softer and more malleable. During annealing, the steel's microstructure undergoes transformation, typically yielding a combination of coarse and fine grains.***

2) NORMALIZING: ***Similar to annealing, normalizing involves heating the steel to a specific temperature, but instead of slow cooling, it is cooled in still air. This process enhances the grain structure and uniformity of the steel, augmenting its strength and resilience. The resulting microstructure may feature finer grains compared to annealing.***

3) QUENCHING: ***Quenching involves rapidly cooling the steel from a high temperature using a quenching medium like water, oil, or air, imparting a sudden shock. This swift cooling solidifies the steel's microstructure, leading to increased hardness and strength. Depending on the quenching medium and cooling rate, the microstructure may include phases such as martensite, renowned for its hardness.***

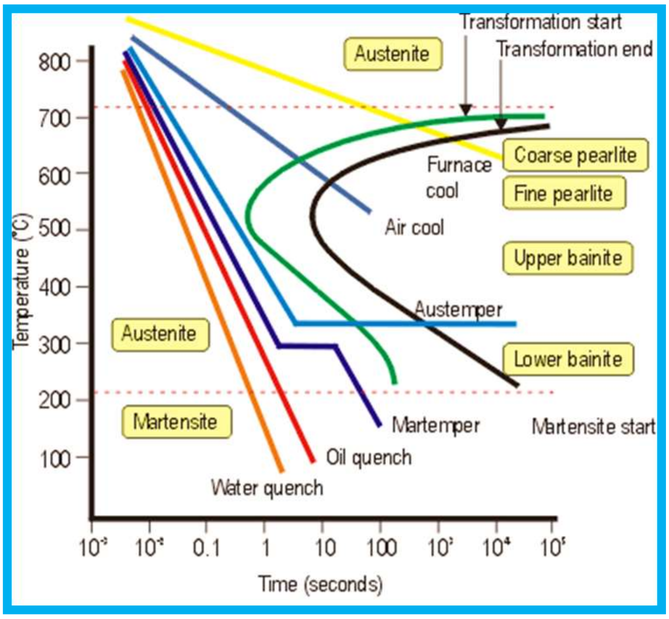
***4) TEMPERING:* This process balances hardness and toughness by reheating quenched steel and subsequently cooling it, forming tempered martensite and enhancing overall performance.**

***5) AUSTEMPERING:* This method generates a bainite microstructure in steel by holding it just above the martensite transformation range after quenching, resulting in a fine-grained structure with high strength and ductility.**

Schematic of heat treatment processes (TTT Diagram)

Limitations of Heat Treatment:

1. Not all materials are suitable for heat treatment.
2. Achieving uniform treatment across the material can be challenging.
3. Alters surface properties, potentially affecting the final finish.
4. Requires specialized equipment and precise control of parameters.
5. May lead to distortion or cracking of the material.



(TTT Diagram)

Applications of Heat Treatment:

1. Enhances material hardness to improve wear resistance.
2. Reduces hardness to relieve stress for shaping purposes.
3. Improves toughness and strength of materials.
4. Facilitates shaping processes while reducing tool wear.
5. Removes stress induced during manufacturing processes.

Sample Preparation

Metallography encompasses the preparation, examination, and analysis of metallic materials' microstructure. The process involves several steps, including cutting, mounting, grinding, polishing, and etching samples to reveal their internal structures under a microscope.

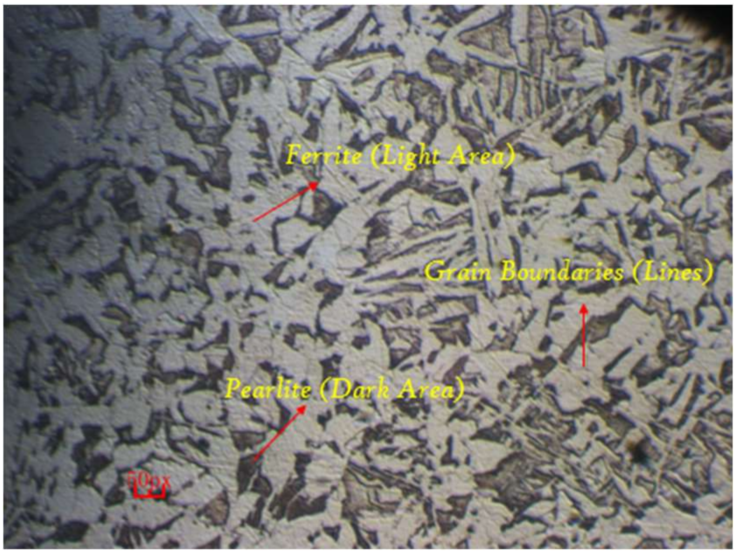
GRINDING: *The initial step in sample preparation is grinding, aimed at removing surface irregularities and achieving a flat starting surface. A belt abrasive grinder is employed for this purpose, where the sample is placed on the belt at a 90-degree angle,* *applying uniform pressure and holding it firmly. Gradually, a finer surface finish is achieved. It's crucial to ensure both sides of the surface are flat, as this sets the foundation for accurate subsequent polishing and etching procedures.*

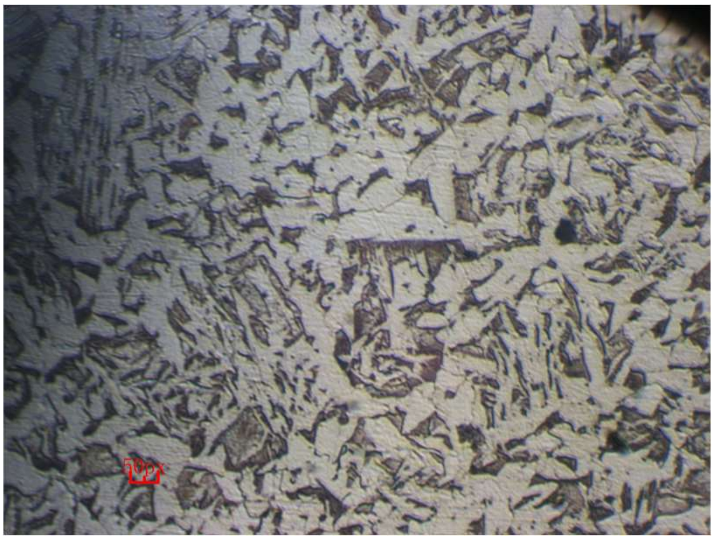
POLISHING: *Following grinding, the sample undergoes polishing using abrasive paper, commonly Silicon carbide (SiC) ranging from 220 to 2000 grit size. The specimen is placed face down on the abrasive surface and slid forward against it. After rotating the specimen 90 degrees, the process is repeated. Cloth polishing follows, utilizing polishing wheels with a liquid suspension of Al2O3 (particle size 0.2 μm) and water to attain a mirror finish.*

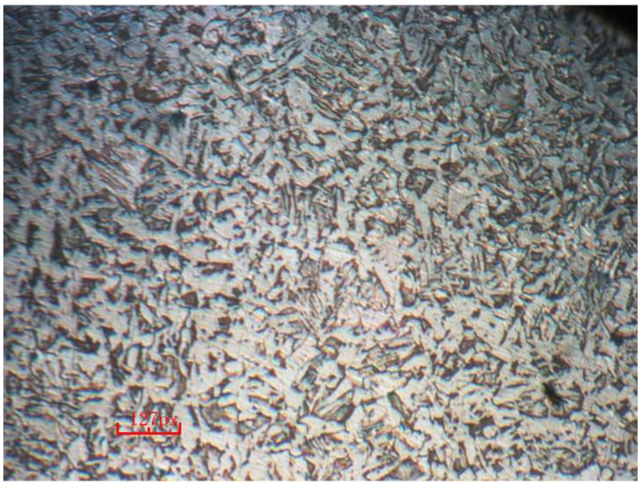
ETCHING: *Etching involves using a chemical reagent to selectively attack the polished sample, revealing microstructural details. Grain boundaries, being higher in energy, are more susceptible to etching, resulting in their depression. To expose the crystalline structure, the polished surface is etched using a suitable etching solution. In the lab, a 2% Nitol solution (97% alcohol – 3% Nitric acid) is utilized. It's crucial to avoid over-etching or under-etching the sample. The polished sample is immersed in the Nitol solution for 10 seconds before being dried using a drier.*

Microscopy & Image Analysis

In our laboratory, we utilize an inverted microscope for the examination of material microstructures. This particular microscope configuration features eyepieces and objective lenses positioned beneath the stage, affording us the ability to view specimens from above. Equipped with various magnification lenses, it enables us to zoom in and out to observe fine details. Prepared samples are placed on the stage, and the microscope's light source is employed to illuminate them. Through adjustments in focus and magnification, we can analyze the grains, phases, and other microstructural attributes of the material.





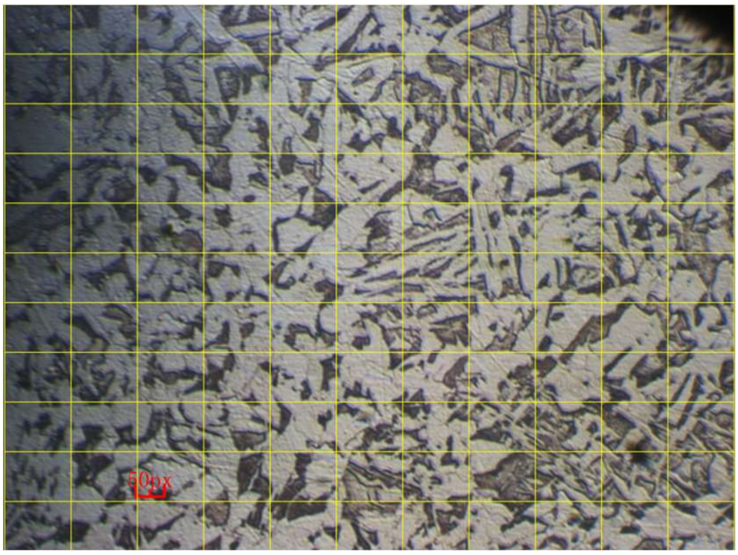
100x (Last Page) & 40x (above) magnified image of sample

Volume Fraction of Phases:

To calculate the volume fraction of phases, we employed the ASTM method. Initially, we captured an image of the microstructure using a microscope and saved it in a file. Subsequently, we imported the microstructure image into a PowerPoint presentation and pasted it onto a blank page. It's imperative that the area depicted in the microscope image is sufficiently large to ensure statistically significant results. We then superimposed a grid table, measuring 11x11, over the image.

Next, we proceeded to count the number of points intersecting the white area, representing the Ferrite phase. Dividing this count by the total number of points and multiplying by 100 yields the volume fraction of the Ferrite phase. To determine the volume fraction of the Pearlite phase, we subtracted the volume fraction of Ferrite from 100.

The formula for calculating the volume fraction is as follows:
Volume Fraction = (Number of points in that phase / Total number of points) x 100



Grain Size Measurement:

To measure grain size, we utilized PowerPoint to paste the microstructure image. Initially, we measured the length of the scale line by drawing a line on it. We then extended this line 10 times its original length.

Next, we randomly placed this extended line over the microstructure, ensuring it intercepts grain boundaries. We counted the number of times the line intercepted grain boundaries. To ensure accuracy, we rotated the line to five different angles, systematically covering the entire microstructure.

For each rotation, we counted the number of intercepts and took the average of these values. Then, we divided the 10 times the length of the scale line by the average number of intercepts. This calculation provided us with the grain size value.

No. of Intercepts:-

Line 1 – 12

Line 2 – 13

Line 3 – 12

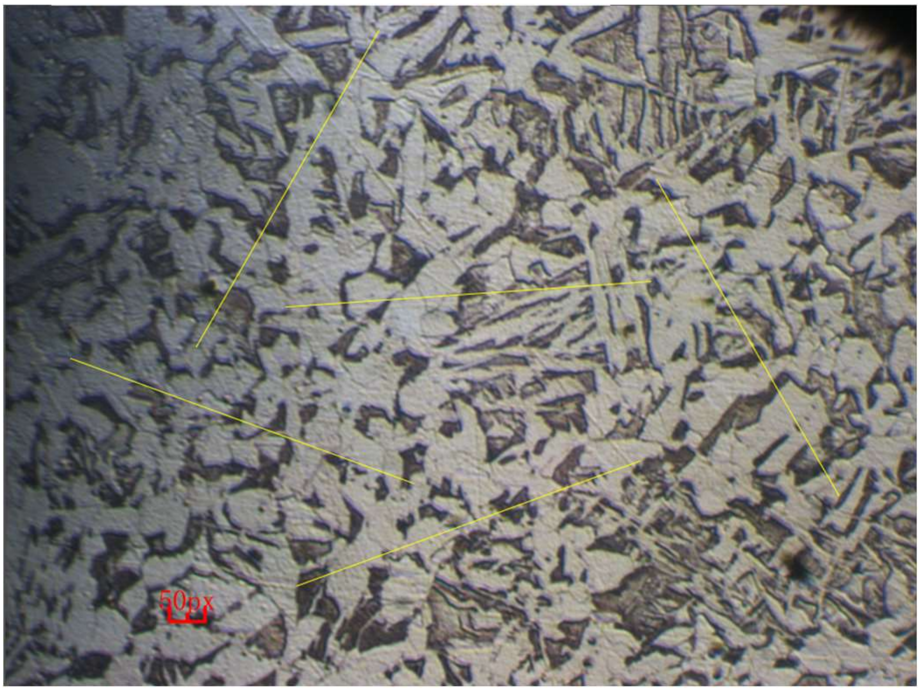
Line 4 - 11

Line 5 – 13

Average – 12.2

Grain Size = 500/12.2

= 40.984 µm



Hardness Measurement:

Vickers Hardness Test:

During the Vickers hardness test in our laboratory, we utilize a Leica microscope equipped with a diamond indenter for precise measurements. The Leica microscope features robust lenses that enable us to observe minute details clearly.

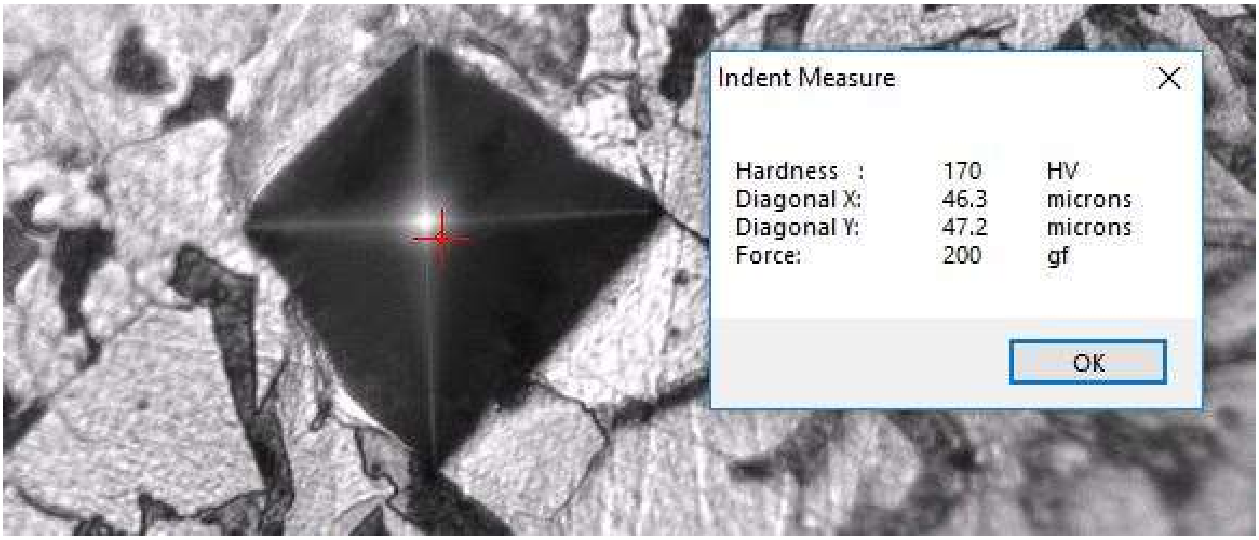
The diamond indenter, with a sharp and tough tip made from diamond, has an included angle of 136°. This indenter is responsible for creating marks, typically in the shape of a diamond, on the material's surface.

METHOD:

1. We begin by ensuring the material's surface is smooth and flat through careful polishing.
2. The Leica microscope is set up and calibrated to ensure accurate measurements.
3. The sample is placed on the microscope's stage.
4. Using the diamond indenter, gentle pressure is applied to the material's surface.
5. After a brief period, the applied force is slowly lifted off.
6. The microscope is then used to measure the lengths of the diagonals left by the diamond indenter on the material's surface.

FORMULA:

The Vickers Hardness Number (VHN) is calculated using the formula:
$VHN = (1.854 \times F) / d^2$,
where F represents the applied force and d is the average diagonal length, calculated as $(d1+d2)/2$. The units for VHN are gf/mm^2.



Results and Discussion :-

The sample underwent normalizing heat treatment, which is inferred from the following observations and analysis:

1. Volume Fraction of Ferrite Phase:

*The **volume fraction of the ferrite phase was determined to be 0.34 through image analysis**. In a normalized sample, ferrite tends to form due to the even distribution of carbon throughout the material during the heating and cooling process, resulting in a significant presence of ferrite.*

2. Average Grain Size:

The ***average grain size measured at 40.984 µm*** *indicates the normalization process. Normalizing involves heating the material to a specific temperature followed by air cooling, which refines the grain structure, resulting in smaller and more uniform grains compared to the as-cast or as-forged condition. The observed grain size aligns with the characteristic refinement associated with normalizing.*

3. Hardness:

The hardness value of 170 HV at 200 gf load *is consistent with the properties typically observed in normalized samples. Normalization enhances the material's mechanical properties, including hardness, by refining the microstructure and relieving internal stresses. The measured hardness falls within the expected range for normalized steel, further supporting the conclusion of normalizing heat treatment.*

Summary:-

Based on the volume fraction of ferrite, average grain size, and hardness measurement, it is reasonable to conclude that the sample underwent normalizing heat treatment*. This treatment is known to improve the material's mechanical properties and refine its microstructure, aligning with the observed results.*