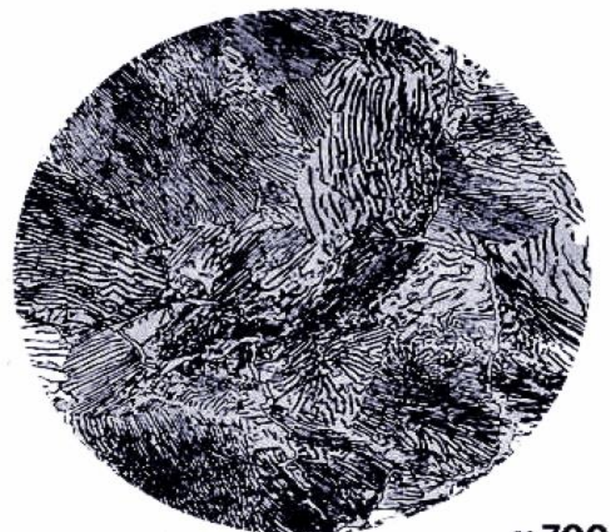
# EXPERIMENT 9

**Subject:** Microstructural examination of metallic materials and calculating the average grain size.

**Objective:** The purpose of this laboratory is to acquaint students with the manner in which metallurgical specimens are prepared for metallographic study, to correlate the relationship between cooling rate and microstructure development and also teaching the determination of grain size by using Heyn's Intercept Method.

**Theory:**



Coarse Pearlite (Annealing) x 700

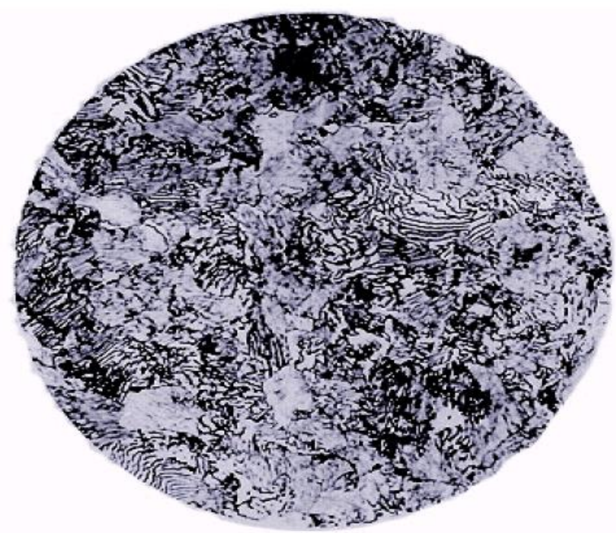
**Process Annealing**

Austenitized at 900°C, a previously cold-worked SAE 1040 specimen, held for 1 hour, then allowed to cool in the furnace itself by turning the oven off thus facilitating a very slow cooling of the sample.

Process Annealing is used to relieve stresses, increase ductility and modify the microstructure.

Process annealing involves recovery, recrystallization and grain growth.

Quenching is often conducted following equiaxed grain formation to facilitate the production of a fine-grained microstructure.



Fine Pearlite (Normalizing) X 700

**Normalizing**

SAE 1040 specimen, Austenitized at 900°C for 1 hour then allowed to cool in air.

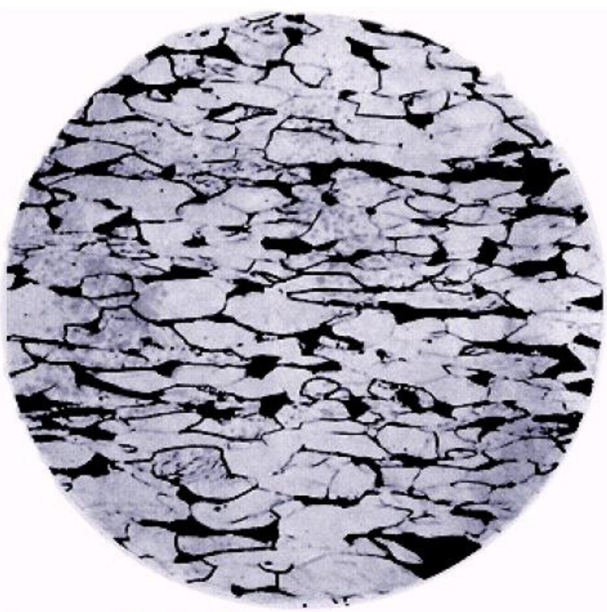
Similar to a Process Anneal, Normalizing is applied to reverse the embrittling effects of cold work. By heating the sample into the austenite range and allowing recrytallization, the grain structure is refined and relatively small grains are formed by allowing the sample to slow-cool in air.

Martensite (Quenching) X 700

## Quench Hardening

SAE 1040 specimen, Austenitized at 900°C for 1 hour, then rapidly quenched in cold water.

Of the various microstructures that may be produced for a given steel alloy, martensite is the hardest and strongest and, in addition, the most brittle.



Carbide/Ferrite (Tempering) X 700

## Tempering

SAE 1040 specimen, Austenitized at 900°C for 1 hour then water quenched. The specimens are reheated to 400°C in another furnace for 30 minutes and are then removed and allowed to cool to room termperature in air.

Martensite in the as-quenched state, in addition to being very hard, is so brittle that it cannot be used for most applications. The ductility and toughness of martensite are enhanced, and the internal stresses relieved, through the Tempering process.

Bainite (Austempering) X 700

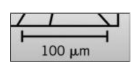
**Austempering**

SAE 1040 specimen, Austenitized at 900°C for 1 hour, then the specimen is quenched in a fused salt bath (mixture of Na-nitrate and Nitrite in equal proportion) that is maintained at 400°C. After 30 minutes, the specimen is removed from the bath and quenched in water or allowed to air cool at room temperature.

Austempering facilitates the formation of a Bainitic structure that exhibits an excellent balance between high strength and ductility.

**Calculation the Avarage Grain Size via Intercept Method:** The method consists of finding out the number of grains intercepted by a line of known length at a magnification on the ground-glass screen of a microscope, or a micrograph, or by means of graduated eye piece.

- Draw a line of known length (mm) on the micrograph in a random orientation.
- Count the number of times the line intercepts a grain boundary.
- Measure the length of the scale bar (mm)
- Convert length to the units of the scale bar (μm)
- Magnification is ratio of:




$$M = \frac{measured\ scale\ length}{number\ appearing\ by\ scale\ bar}$$

- And calculate the average grain size:

$$Average\ Grain\ Size = \frac{Line\ Length}{Number\ of\ Grains}$$

- Apply this calculation for all the lines you drew and take the average of them all.

**LAB Procedures**

1. Polish and etch all specimens (a), (b), (c) and (d) taken from previous experiment.
2. Take microstructural photos of all specimens.
3. Investigate and compare all microstructures and learn the effects of heat treatment on the microstructure.
4. Calculate the average grain size for all specimens and compare them.
5. Prepare a lab report.