The Jominy end quench test

Introduction :

The Jominy end quench test is used to measure the hardenability of a steel, which is a measure of the capacity of the steel to harden in depth under a given set of conditions. This TLP considers the basic concepts of hardenability and the Jominy test.

Knowledge about the hardenability of steels is necessary to be able to select the appropriate combination of alloy steel and heat treatment to manufacture components of different size to minimize thermal stresses and distortion. The Jominy end quench test is the standard method for measuring the hardenability of steels. This describes the ability of the steel to be hardened in depth by quenching.

Hardenability depends on the chemical composition of the steel and also be can affected by prior processing conditions, such as the austenitizing temperature. It is not only necessary to understand the basic information provided from the Jominy test, but also to appreciate how the information obtained can be used to understand the effects of alloying in steels and the steel microstructure.

Hardenability

Hardenability is the ability of a steel to partially or completely transform from austenite to some fraction of martensite at a given depth below the surface, when cooled under a given condition. For example, a steel of a high hardenability can transform to a high fraction of martensite to depths of several millimetres under relatively slow cooling, such as an oil quench, whereas a steel of low hardenability may only form a high fraction of martensite to a depth of less than a millimetre, even under rapid cooling such as a water quench. Hardenability therefore describes the capacity of the steel to harden *in depth* under a given set of conditions.

Steels with high hardenability are needed for large high strength components, such as large extruder screws for injection moulding of polymers, pistons for rock breakers, mine shaft supports, aircraft undercarriages, and also for small high precision components such as die-casting moulds, drills and presses for stamping coins. High hardenability allows slower quenches to be used (e.g. oil quench), which reduces the distortion and residual stress from thermal gradients.

Steels with low hardenability may be used for smaller components, such as chisels and shears, or for surface hardened components such as gears.

Hardenability can be measured using the Jominy end quench test.

Jominy end quench test

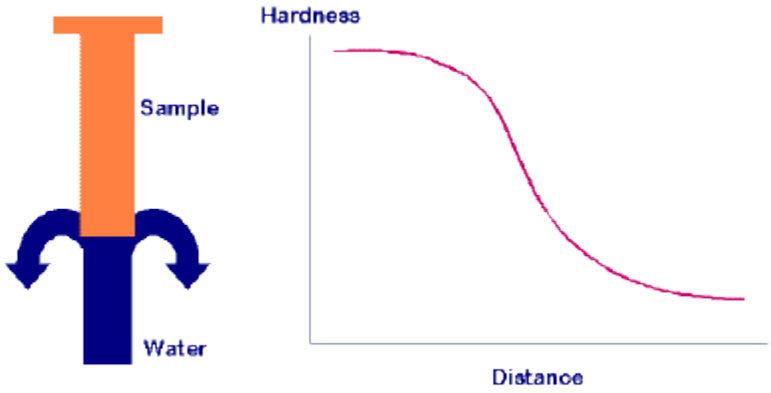
The test sample is a cylinder with a length of 102 mm (4 inches) and a diameter of 25.4 mm (1 inch).

Jominy test specimen

The steel sample is *normalised* to eliminate differences in microstructure due to previous forging, and then *austenitised*. This is usually at a temperature of 800 to 900°C. The test sample is quickly transferred to the test machine, where it is held vertically and sprayed with a controlled flow of water onto one end of the sample. This cools the specimen from one end, simulating the effect of quenching a larger steel component in water.

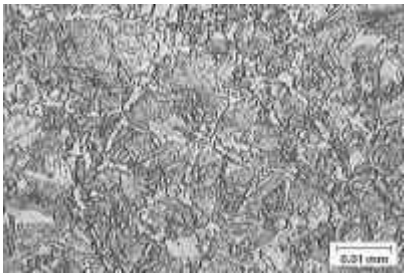
Jominy test machine

The cooling rate varies along the length of the sample from very rapid at the quenched end, to rates equivalent to air cooling at the other end.

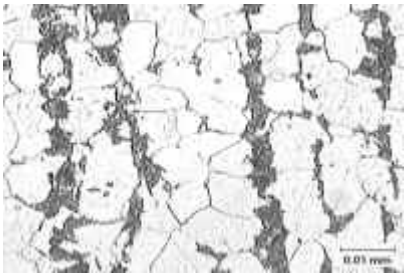


The round specimen is then ground flat along its length to a depth of 0.38 mm (15 thousandths of an inch) to remove decarburised material. The hardness is measured at intervals from the quenched end. The interval is typically 1.5 mm for alloy steels and 0.75 mm for carbon steels.

High hardness occurs where high volume fractions of martensite develop. Lower hardness indicates transformation to bainite or ferrite/pearlite microstructures.



Martensite



Ferrite/pearlite

Jominy end quench hardness data for two steels of different hardenability can be seen in a later section of this TLP, with images of the microstructure variation along the length of the sample. Similar tests have been developed in other countries, such as the SAC test, which uses a sample quenched from all sides by immersion in water. This is commonly used in the USA.

Source: http://www.doitpoms.ac.uk/tlplib/jominy/jominy.php