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CHAPTER 62

COLD TREATMENT OF METALS

Mechanism of Austenite Transformation, Conversion of Retained Austenite, Product Improvement of Ferrous Alloys, Mechanism of Precipitation Hardening, Processes Involving Physical Change, Methods of Cold Treatment

THE application of sub-atmospheric cooling of metals for product improvement or as a necessary processing method has increased in recent years. This acceptance has been brought about by a better scientific understanding of the structural changes that occur in metals at low temperatures, the development of new alloys or processes and the availability of commercial low-temperature equipment for continuous industrial operation rather than intermittent laboratory testing. It is recognized that cold treatment of metals has been a somewhat controversial topic over the years. Expert opinion has often been divided in view of conflicting claims, incomplete data and the inability to measure accurately minute structural changes taking place in many metals. This chapter will attempt to present a consensus of metallurgical opinion regarding the permanent microstructure changes involved in the cold treatment of metals, in addition to a summary of those processes where cold treatment is employed to produce reversible physical change. Chapter 63 discusses the mechanical properties of metals existing at low temperatures.

MECHANISM OF AUSTENITE TRANSFORMATION

The structure of hardenable steel at room temperature consists of a mixture of ferrite and carbide, the exact dispersion of these two phases being dependent on the prior heating and cooling cycles. The atoms of iron at room temperature are arranged in a body-centered cubic crystal lattice form known as alpha iron which will dissolve limited amounts of carbon and alloy elements to form a solid solution named ferrite. Since the limiting solubility of carbon in alpha iron is about 0.01 percent at room temperature, the excess carbon present in steel will be found as free iron carbide (cementite) or complex alloy carbides.

When ferrite is heated to a given temperature an allotropic transformation takes place with rearrangement of the iron atoms in a face-centered cubic crystal form known as gamma iron, which has a maximum solubility of 1.7 percent carbon in straight carbon steel at 2065 F. This solid solution of carbon in gamma iron is named austenite and is non-magnetic. Actually, the process of austenitizing takes place over a range of temperature known as the critical range in all cases except eutectoid steel. The lowest temperature of transformation for straight carbon steels under equilibrium conditions is 1333 F. Critical temperatures for steels are available in the literature and vary with carbon content, alloy elements and rate of heating or cooling. Austenitizing consists of nucleation of austenite grains, solution of excess carbide and growth of the austenite grains as a function of increased time and temperature.

Our ability to vary the mechanical properties of steel through heat treatment is dependent on controlling the allotropic transformation of austenite upon cooling. Studies of austenite transformation under controlled isothermal conditions have yielded valuable data as a guide to the metallurgist working with heat treating processes under continuous cooling conditions. Isothermal transformation diagrams for most of the conventional steels are available typical of Fig. 1 which illustrates a SAE 1080 (eutectoid) steel. When austenite is cooled to temperature levels below the critical range, down to approximately 1000 F the transformation products are lamella mixtures of ferrite and iron carbide (cementite) known as pearlite. Austenite requires considerable time to transform in the upper portion of this temperature range, producing a coarse pearlite, whereas at the nose of the curve, transformation occurs rapidly to produce a fine pearlite at approximately 1000 F.

Pearlite does not form at temperatures below about 1000 F, but instead austenite transforms to a product known as bainite, having a feathery appearance when formed in the upper portion of the range, becoming more acicular or needle-like at lower temperatures of transformation. The diagram shows the transformation of austenite to its decomposition products, pearlite or bainite, to be a function of time down to a certain temperature M_s, below which transformation to a product known as martensite occurs as a function of temperature independent of time. The transformation product forming below the M_s temperature has a body-centered tetragonal crystal form super-saturated with carbon. This nonequilibrium structure is hard, brittle and in a severe state of stress. Since martensite occupies a greater volume than austenite, a resultant dimensional expansion takes place. Martensite appears acicular in structure and is usually associated with some untransformed austenite, known as retained austenite. As-quenched steel is unsuitable for practical application and is always given a stress-relieving or tempering operation consisting of reheating to some temperature below the critical range. The relief of internal stress produces a

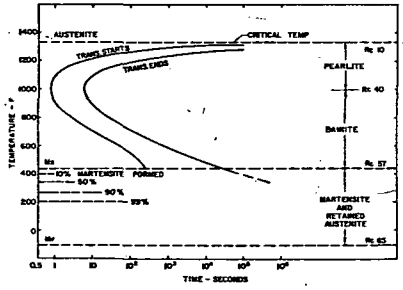

Fig. 1 .... Isothermal Transformation Diagram for Eutectoid Steel