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I- INTRODUCTION

Many times a materials problem is really one of selecting that material which has the right combination of characteristics for a specific application. Therefore, the persons who are involved in the decision making should have some knowledge of the available options. This extremely abbreviated presentation provides an overview of some of the types of metal alloys, ceramics, and polymeric materials, their general properties, and their limitations.

II- TYPES OF METAL ALLOYS

Metal alloys, by virtue of composition, are often grouped into two classes, ferrous and nonferrous. Ferrous alloys; those in which iron is the principal constituent include steels and cast irons. These alloys and their characteristics are the first topics of discussion of this section. The nonferrous ones; all alloys that are not iron based.

a) FERROUS ALLOYS

Ferrous alloys those in which iron is the prime constituent, are produced in larger quantities than any other metal type. They are especially important as engineering construction materials. Their widespread use is accounted for by three factors: (1) iron containing compounds exist in abundant quantities within the Earth's crust; (2) metallic iron and steel alloys may be produced using relatively economical extraction, refining, alloying, and fabrication techniques; and (3) ferrous alloys are extremely versatile, in that they may be tailored to have a wide range of mechanical and physical properties.
The principal disadvantage of many ferrous alloys is their susceptibility to corrosion. This section discusses compositions, microstructures, and properties of a number of different classes of steels and cast irons. A taxonomic classification scheme for the various ferrous alloys is presented in Figure 1.

- STEELS

Steels are iron–carbon alloys that may contain appreciable concentrations of other alloying elements; there are thousands of alloys that have different compositions and/or heat treatments. The mechanical properties are sensitive to the content of carbon, which is normally less than 1.0 wt%. Some of the more common steels are classified according to carbon concentration, namely, into low-, medium-, and high-carbon types. Subclasses also exist within each group according to the concentration of other alloying elements. Plain carbon steels contain only residual concentrations of impurities other than carbon and a little manganese.

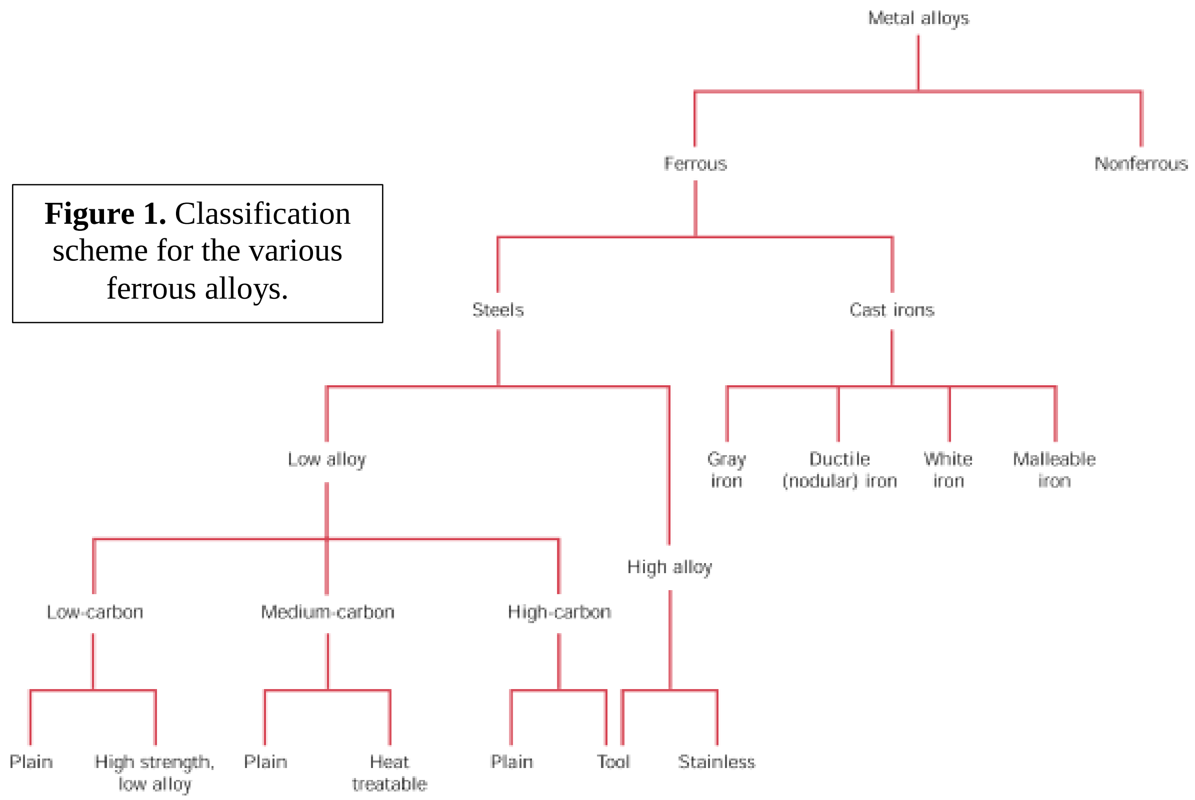

Figure 1. Classification scheme for the various ferrous alloys.

- CAST IRONS

Generically, cast irons are a class of ferrous alloys with carbon contents above 2.14wt%; in practice, however, most cast irons contain between 3.0 and 4.5 wt% C and, in addition, other alloying elements.

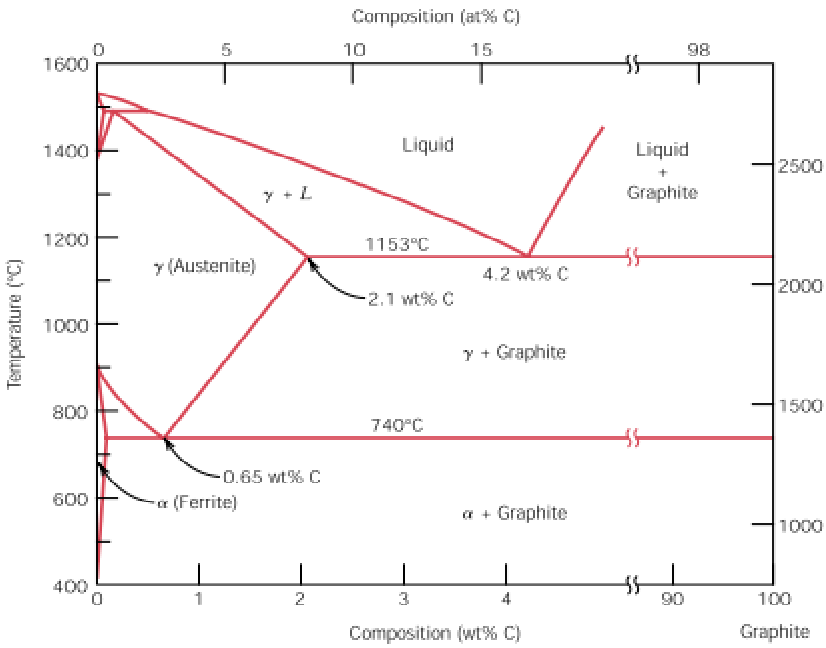

Figure 2. The true equilibrium iron–carbon phase diagram with graphite instead of cementite as a stable phase.

Alloys within this composition range become completely liquid at temperatures between approximately 1150 and 1300°C (2100 and 2350°F), which is considerably lower than for steels. Thus, they are easily melted and amenable to casting. Furthermore, some cast irons are very brittle, and casting is the most convenient fabrication technique.

Cementite (Fe_3C) is a metastable compound, and under some circumstances it can be made to dissociate or decompose to form α ferrite and graphite, according to the reaction:

$$Fe_3C \rightarrow 3Fe(\alpha) + C(graphite)$$

For most cast irons, the carbon exists as graphite, and both microstructure and mechanical behavior depend on composition and heat treatment. The most cast iron types are gray, nodular, white, and malleable.

b) NONFERROUS ALLOYS

Steel and other ferrous alloys are consumed in exceedingly large quantities because they have such a wide range of mechanical properties, may be fabricated with relative ease, and are economical to produce. However, they have some distinct limitations, chiefly: (1) a relatively high density, (2) a comparatively low electrical conductivity, and (3) an inherent susceptibility to corrosion in some common environments. Thus, for many applications it is advantageous or even necessary to utilize other alloys having more suitable property combinations. Alloy systems are classified either according to the base metal or according to some specific characteristic that a group of alloys share. This section discusses the following metal and alloy systems: copper, aluminum, magnesium, and titanium alloys, the refractory metals, the superalloys, the noble metals, and miscellaneous alloys, including those that have nickel, lead, tin, zirconium, and zinc as base metals.

On occasion, a distinction is made between cast and wrought alloys. Alloys that are so brittle that forming or shaping by appreciable deformation is not possible ordinarily are cast; these are classified as cast alloys. On the other hand, those that are amenable to mechanical deformation are termed wrought alloys.

In addition, the heat treatability of an alloy system is mentioned frequently. ‘‘Heat treatable’’ designates an alloy whose mechanical strength is improved by precipitation hardening or a martensitic transformation (normally the former), both of which involve specific heat-treating procedures.

Questions

1) (A) List the four classifications of steels.
   (B) For each, briefly describe the properties and typical applications of steels.
2) (A) Cite three reasons why ferrous alloys are used so extensively
   (B) Cite three characteristics of ferrous alloys that limit their utilization.
3) Compare steel and cast iron with respect to (a) composition and heat treatment, (b) microstructure, and (c) mechanical characteristics.
4) Is it possible to produce malleable cast iron in pieces having large cross-sectional dimensions? Why or why not?