6 Heat Treatment of Metals

Objective	Procedure	
Estimate carbon content of carbon steel	Grind surface smooth, place 3 to 4 drops to 50 per cent nitric acid and alcohol on cold surface. After 1 minute transfer fluid to filter paper. The darkness of the stain will determine amount of carbon.	
Test for manganese	Grind surface smooth, place 3 to 4 drops of 50 per cent nitric acid ar alcohol on the surface. Add enough sodium bismuthate reagent until a brow cluster of particles appears. Wait for 3 minutes and add a drop of nitric aci If a pink colour appears, there is manganese in the metal.	
Separate 300 stainless from monel	Monel shows an immediate reaction to concentrated nitric acid and usual becomes blue-green.	

Table 1.1. Typical procedures for chemical reaction test	Table 1.1.
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Spark Test

The spark test can be useful in separating alloys that contain known alloying elements. It is especially helpful in determining wide variations in carbon content, such as separating mild steel, which has good weldability, from carbon tool steel, which should not be welded by ordinary procedures. Spark testing is based on the theory that heat generated by friction between the alloy and the grinding wheel and oxygen in the air cause the particles to burn. The technician analyses the burning pattern and relates it to patterns from past experience and reference charts. In the analysis the technician is concerned with volume, length from wheel to burn-out, colour and explosions along the stream or at the end of the spark pattern. Sparks from iron carbon alloys develop a very distinctive appearance. The spark pattern is easy to photograph in colour by using colour film of at least ASA 160 (tungsten) and setting the shutter speed no slower than 1/30 seconds. With a little skill, rapid identification can be made with an inexpensive portable grinder (Fig. 1.4).





Cast iron and the alloy steel may also be separated with experience and characteristic spark patterns. (Fig. 1.5).



Fig. 1.5. Spark patterns from a few selected steels.

Molybdenum, copper	High temperature	strength
Nickel, vanadium	High temperature	strength
Chromium	High temperature	strength

Control of thermal expansion is necessary in some types of instrumentation. This control may be necessary over a wide range of temperatures. A nickel-iron alloy called 'invar' has been developed for the purpose of resisting the process of thermal expansion. Invar has only one-fifth the expansion of structural steel. Austenitic cast irons containing a high nickel content have high electrical resistivity. Heating elements are made from iron-nickel alloys. Magnetic clutch units are made by alloying iron and aluminium. These are just a few of the many alloys created to perform the many special tasks required in industrial applications.

Aluminium Alloys

Aerospace technology has made aluminium alloys some of the most important of the lightweight metals. Today aluminium products are common to almost everyone. Yet it is interesting to look into the last century when aluminium was just being developed. Commercial production of aluminium was not practical until the electrolysis of the molten bath was discovered. Today, mass production of aluminium can produce high purity (99.99 per cent) products or alloys with exacting controls. There are many applications of aluminium alloys, such as:

- 1. Aircraft and spacecraft components.
- 2. Deoxidising steel.
- 3. Kitchenware.
- 4. Electrical transmission lines.
- 5. Making paint.
- 7. Structural assemblies.

Aluminium alloys can be produced with a wide range of mechanical properties. A few typical properties are shown in Fig. 1.18 through Fig. 1.21.



Fig. 1.18. A comparison of the strength of structural steel and structural aluminium, two metals used in construction.

It is a well-known principle in the field of metallurgy that ordinary ferrous metals exhibit a characteristics loss of toughness at some low temperature. The temperature at which normally ductile metals fail with a brittle fracture is called the transition temperature. The transition temperature may be near the freezing point of water or lower.



Fig. 2.8. An elementary crystal cell (simple cubic).

Crystal Lattices of Metals

As has been mentioned, the crystalline state is characterised primarily by an ordered regular arrangement of atoms in space. This implies that each atom in a crystal has the same number of nearest atoms– neighbours, spaced the same distance apart from the atom considered.

The tendency of atoms (ions) in metal to occupy positions as close as possible to one another, i.e., to arrange themselves as dense as possible results in that there are only a few possible combinations of mutual arrangement of atoms in crystals of metals.

There exist a number of schemes and methods for description of mutual arrangement, or packing, of atoms in crystals. The mutual arrangement of atoms in one of the crystal planes is shown in Fig. 2.7. The imaginary lines drawn through the centres of atoms form a lattice with atoms (positive ions) located in the lattice sites; this is what is called a crystal plane. Multiple reproduction of parallel crystal planes forms a space crystal lattice whose sites are locations of atoms (ions). The distances between the centres of neighbouring atoms are measured in angstroms ($1\text{\AA} = 1.10^{-8}$ cm) or in X-units ($1 \text{ kX-unit} = 1.00202 \text{ \AA}$).

Mutual arrangement of atoms in space and interatomic distances are determined by X-ray structural analysis. The positions of atoms in a crystal can be very conveniently depicted in the form of space arrangements which are called elementary crystal cells. An elementary crystal cell is understood as the least combination of atoms which, upon multiple reproduction in space, gives a space crystal lattice.

The simplest type of crystal cell is the cubic lattice. In a simple cubic lattice, atoms are arranged (packed) not quite densely.

Atoms tend to occupy positions as close as possible to one another and thus form other types of crystal lattice: body-centred cubic (bcc, Fig. 2.9a), face-centred cubic (f.c.c., Fig. 2.9b) and close-packed hexagonal (cph, Fig. 2.9c).

The circles which depict atoms can be located in the centre and at the corners of a cube (bodycentred cube), in the centres of cube faces and at the corners (face-centred cube), or in the form of a hexahedron with another hexahedron being half-inserted into it, with the three atoms of the upper plane of the latter hexahedron being inside the hexahedral prism (hexagonal lattice). A real metal is composed of a plurality of crystals. Individual crystals are only fractions of a millimetre in size, so that many thousands of crystals may be present in 1 cm^3 of metal volume. Since these crystals are randomly oriented, there is roughly the same quantity of differently oriented crystals in any direction. As a result, the properties of this polycrystalline body are the same in all directions, though the properties of every crystal, it is composed of, depend on the crystal orientation. This phenomenon is called quasiisotropy.

TYPES OF DEFECTS IN CRYSTALS

Different types of defects are found in most of crystals. Crystals have mainly three types of defects:

Line Defects

Line defects involve the edge of extra plane of atoms. They are of two types: (i) edge dislocation; and (ii) screw dislocation.

Point Defects

The point defects are caused by missing atoms, extra atoms or displaced atoms. The point defects are classified as:

(i) Vacancies; (ii) substitutional impurity; (iii) interstitial defects; (iv) Frenkel defects; (v) Schottky defects; and (vi) phonon.

Vacancies

Vacancy is the simplest point defect, which involves a missing atom. Such defects are due to imperfect packing. They also arise due to thermal vibration of atoms at high temperature because at high temperature, an atom can jump out and go to lowest energy position, (Fig. 2.19). The vacancies may vary from one in 10^{18} atoms at room temperature to one in 10^4 atoms near melting point. Due to some external effects the vacancies may increase and in extreme cases may be 1 to 3 per cent.



Fig. 2.19. Vacancy defect.

Substitutional defects

Sometimes a foreign atom replaces the parent atom of the lattice and thus occupies the position of parent atom (Fig. 2.20).