Chapter 1-3

FERROUS GROUP OF METALS AND ALLOYS - STEELS

CONTENTS

Para.
1 Introduction
3 Carbon steels (mild)
4 Steel alloys
5 Chromium steel
11 Cobalt steel
13 Manganese steel
17 Molybdenum steel
20 Nickel alloys
21 Permalloy
22 Monel metal
23 Nickel steel
26 Nickel chrome steel (nichrome)
27 Nickel silver (german silver)
28 Silicon steel
32 Silver steel
33 Tool steel
35 Tungsten steel
40 Vanadium steel

Introduction

1 Steel is produced from cast iron by several methods; these methods vary in the processes which reduce the amount of carbon and silicon and eliminate such undesirable elements as sulphur and phosphorous. The chief processes used are the electrical smelting and Basic Oxygen System (B.O.S.), which uses commercially pure (99 per cent) oxygen.

2 These processes depend mainly upon the oxidising effects of an air blast on molten iron and they vary in the method of applying the heat and air, also in the type of fluxes employed for different grades of iron used. Although strictly speaking all steel is an alloy, it is usually classified under two groups, plain carbon steel and steel alloy.

CARBON STEELS (MILD)

3 Steels whose properties are primarily determined by the percentage of carbon (C) present. They also include up to 1.6% Mn, up to 0.6% Si, up to 0.1% S and a small amount of Phosphorous (P). It does not contain any Chromium (Cr), Nickel (Ni), Molybdenum (Mo) etc. It is normally supplied in three classes; viz:

3.1 Mild - contains less than 0.15% carbon.

3.2 Medium hard - contains 0.15 to 0.3% carbon.

3.3 Hard - contains more than 0.3% carbon.

STEEL ALLOYS

4 A number of steel alloys have been developed for special purposes, several of the alloys having particular applications in aircraft construction. Elements are added to the metals in widely varying quantities, and may be used singly or in combination in order to produce alloy steels for some specific purpose. The effects of some elements may be to improve grain structure, to give increased hardness, toughness and ductility, or in the case of stainless steel, to resist corrosion. The most frequently used alloy steels are dealt with in para 20 to 22.

Chromium steel

5 Chromium (in the form of ferro-chromium) is alloyed with steel alone at 0.50 to 1.50%.

6 Special air-hardening steels are made from chromium steel, the chromium content being from 12 to 17 per cent and carbon from 1 to 2.25 per cent; higher percentages of chromium are used in the manufacture of stainless steels of which there are many types, each having a different composition and characteristics for some particular purpose. The high chromium content is common to all these steels but there are two groups.

7 The first group consists of alloys with a low nickel content, and these can be hardened and tempered by heat-treatment. They are magnetic, and are resistant against corrosion in the heat-treated condition only.

8 The second group of alloys are generically termed Austenitic steels. Commonly, they have high contents of nickel, ni-chrome, or manganese, to retain austenite at atmospheric temperatures. They are widely used in applications requiring high levels of heat and corrosion resistance, and are non-magnetic.

9 Hardening is effected by working the material, and softening or annealing is effected by heating it to a temperature of 1100°C. and then cooling rapidly. Forging temperatures are very high, being in the region of 980°C and 1100°C.

10 Stainless steel is manufactured in a variety of forms and may be cast, rolled, forged or drawn, and for each of these purposes it is possible to vary the composition of the alloy in order to give a particular property. Typical compositions of these alloys are given in the relevant specification to which the material has been made, i.e. B.S. D.I.N., D.T.D. etc., also termed Chromax, an iron-based alloy, with from 20 to 30% nickel and 15 to 20% chrome.

Cobalt steel

11 Cobalt is very similar to nickel in appearance and properties, and it is usually alloyed with steel for use in the production of permanent magnets and high speed tool steel. Tungsten vanadium steel alloys may be improved by the addition of cobalt, which has the effect of making the alloy less sensitive to critical temperatures during heat-treatment processes.

12 The amount of cobalt required for the different alloys varies widely from 5 to 12%, the alloys also normally containing from 14 to 20% W, 4% Cr., 1 to 2% V., 0.8% C., with traces of molybdenum (Mo). Special heat-treatment is necessary for all cobalt steels after forging, otherwise cracking may result during cooling.

Manganese steel

13 Manganese steel is very tough and has the property of work hardening slowly, and becomes hard and brittle if allowed to cool. Pearlitic manganese steels are frequently used, the manganese content of which is usually from 1 to 1.90 per cent, the carbon content being from 0.10 to 0.50 per cent.

14 This alloy is usually quenched in oil during hardening processes, and when the carbon content is high, it is dangerous to quench it in water.

15 Austenitic manganese steel contains from 11 to 15% manganese and a carbon content of 1.0 to 1.40%, and is so tough and hard that the metal hardens as the tool is being forced into the work. During machining operations, the correct speeds and feeds should be used, special high-speed tools also being necessary. If the carbon content exceeds 1.40% the alloy decreases in toughness and strength.

16 The result of adding manganese to steel is for the manganese to:

16.1 Combine with some of the carbon to form carbide of manganese.

16.2 Act as a purifier, by eliminating gases and oxides.

16.3 Combine with any sulphur, nullifying its harmful effect.

16.4 The critical temperatures for manganese steel are increased in range so facilitating heat-treatment processes, the range from minimum to maximum being as high as 65°C. in some instances.

16.5 Austenitic manganese steel has an electrical resistance seven times that of pure iron, is practically non-magnetic, and can be cast, forged and rolled.

Molybdenum steel

17 This alloy has physical properties similar to those of iron, and chemical properties similar to those of a non-metal. The alloys contain pure molybdenum which is a soft, ductile metal, similar in colour to platinum (Pl).

18 The percentage of this metal in the alloy composition is between 0.25 to 0.40, but may be as high as 1% if alloyed with manganese. The effect of molybdenum on steel is to slow down any structural change caused by heat-treatment and to give greater depth to hardening; it also gives toughness, structural stability, higher temperature strength and absence of temper brittleness.

19 When the molybdenum content is low it does not affect the forging, rolling, machining or welding properties of the alloy. Molybdenum is mostly used in conjunction with other elements such as chromium and manganese to give increase in tensile strength or additional depth-hardening qualities. It seals well with pyrex glass and can be spot welded to iron and steel.

NICKEL ALLOYS

20 Where nickel is the main constituent of an alloy (50.0% +) it is referred to as a 'nickel alloy'. There are two main commercial varieties, detailed in para 21 and 22.

Permalloy

21 Denotes a high magnetic permeability at low field strength and low hysteresis loss. Original composition was 78.5% Ni, 21.5% Fe, but the name now generally covers numerous alloys with other elements, e.g. Cu, Mo, Cr, Co and Mn.

Monel metal

22 A high strength, 52 kg/mm^2 (33 tons/in^2) alloy, with good elongation characteristics (45%) and high corrosion resistance. Typically composed of 68.0% Ni, 29.0% Cu, 3.0% C with trace elements of Mg, S, and Fe.

NICKEL STEEL

23 Nickel steel has several new properties in comparison with carbon steel. The addition of nickel increases the tensile strength and the yield point, and gives increased hardness without loss of ductility when the steel is in either the annealed or heat-treated state. The alloy is invariably used after heat-treatment in order that full advantage may be taken of the properties given to the alloy by the nickel.

24 Varying amounts (between 0.5 and 6.0%) are added to increase the strength in the normalised condition, enabling hardening to be performed in oil or air, instead of water; or to increase the core strength of carburised parts.

25 Critical temperatures are spread over a wider range during heat-treatment, and the alloy can also be subjected to relatively high temperatures for long periods without undue injury to the metal.

Nickel chrome steel (nichrome)

26 Steel containing nickel and chromium as alloying elements. From 1.5 to 4.0% Ni and from 0.5 to 2.0% Cr. are added to give an alloy of high tensile strength, hardness and toughness. The alloys are particularly suited for highly stressed aero-engine parts, and armour plate.

Nickel silver (german silver)

27 A series of alloys of Cu, Zn and Ni, within the following limits : 25.0 to 30.0% Cu, 5.0 to 35.0% Ni, 10.0 to 35.0% Zn.

SILICON STEEL

28 An iron or steel alloy, to which 0.75 to 4.0% silicon (from ferro-silicon) has been added.

29 When the silicon level in steel is from 2.5 to 4.0%, it is more correctly known as low-hysteresis steel, with high permeability and electric resistance characteristics.

30 Silicon acts as a deoxidiser, and assists in producing steel which is practically free from blowholes.

31 It is particularly used in sheet form in transformer cores. Silicon-manganese steel is used in the manufacture of flat leaf springs, whilst silicon-chromium alloys are used for making internal combustion engine valves in which the high temperatures are harmful to ordinary steel.

SILVER STEEL

32 A bright drawn carbon steel containing up to 0.3% si, 0.45% mg. 0.5% Cr, and 1.25% C, and is low in P and S. Widely used in machine tooling.

TOOL STEEL

33 Steel alloys containing 0.6 to 1.6% C, with high proportions of alloying metals, Ti, Cr, Mo.

34 The main qualities required are hardness, toughness and ability to keep a cutting edge. Such steels are usually supplied quenched and tempered to obtain these properties.

TUNGSTEN STEEL

35 Tungsten is a hard, grey, corrosion and heat resistant metal, also known as wolfram.

36 It is a carbide forming element and quantities (up to 0.50%) may be used for steels employed in dies, drills and cutting tools.

37 In special high-speed steels, the proportion may be increased to 20.0%.

38 Permanent magnets may be made containing from 5.0 to 7.0 per cent tungsten, but cobalt steel is more efficient for the purpose.

39 It is also widely used in wire elements for electric incandescent lamps.

VANADIUM STEEL

40 Vanadium occludes oxygen and nitrogen, giving a close grained and uniform structure. The addition of vanadium improves tensility and ductility, so that the alloys have great resistance to shock and fatigue.

41 Vanadium alloys respond well to heat treatment, and are used in the production of large forgings due to the low degree of distortion.

42 A typical alloy composition could be: 0.4 to 0.5% C, 1.1 to 1.5% Cr, 0.15 to 0.2% V, balance Fe. Up to 0.5% V may be used.