RECENT DEVELOPMENTS IN CORROSION RESISTANT NON-FERROUS METALS AND ALLOYS (*)

S.S.Misra and T.L.Rama Char
Electrochemistry Laboratory,
Indian Institute of Science,
Bangalore.

The importance of iron and its alloys has resulted in the classification of all the other metals and their alloys as non-ferrous. The latter vary widely in their properties and the mechanism of corrosion resistance. Parameters important for the resistance are: physical, chemical, electrochemical, thermodynamic and metallurgical. The corrosion reaction is primarily electrochemical and the basic kinetic principles are now relatively well understood. The reaction rates, of course, are difficult to predict, being highly dependent upon the nature of the environment, surface, and metallurigcal factors. Corrosion control, therefore, remains largely empirical. High purity metals, although corrosion resistant, lack in strength and are also costly. Research and development on alloys, consequently, dominate the recent literature. The present paper reviews the significant developments from 1966.

Environmental Factors:

The eight forms of corrosion, namely, uniform attack, galvanic corrosion, crevice corrosion, pitting, intergranular corrosion, selective leaching, erosion corrosion and stress corrosion, are strongly affected by environmental factors. Severe environments such as high temperature, marine conditions, chemical and others have received attention. The well-known nickel and cobalt base superalloys have been improved in their high temperature behaviour by chromium additions. Uncommon materials suitable for this environment are the alloys of tantalum, niobium, hafnium, vanadium and zirconium. Copper-nickel alloys and titanium are the most widely considered for marine environments. The so-called reactive metals such as titanium, zirconium and tantalum appear quite suitable for use in the chemical environment. Also suitable is a vanadium-niobium alloy; aluminium may be useful too.

(*) Paper for presentation at the Symposium on "Recent Developments in Non-Ferrous Metals' Technology" - 4th to 7th December, 1968, Jamshedpur.

Copper and copper-aluminium-bronze may be the best for tropical waters or for erosion corrosion and cavitation. Stress corrosion continues to baffle, and massive data are being gathered particularly on the light metals such as titanium and aluminium. Also considered are copper- and nickel-base and magnesium alloys. Standardization of test methods is of some concern.

Materials:

Kinetic factors such as the rates of the anodic or cathodic processes have now achieved primary consideration for the classification of materials over the older thermodynamic approach of reversible electrode potential. The importance of light metals in the aerospace has possibly kept alive another one based on weight: light and heavy. The resistance mechanism is quite varied, but many thermodynamically unstable materials are quite stable in practice due to a compact protective layer on the surface. Alloying aims to impart resistance by (1) modifying the cathodic process, (2) modifying the anodic process, and (3) helping to form a protective film on the surface. The fourth desirable effect is dilution of a costlier but resistant parent matrix with a cheaper metal without affecting its resistance.

The major materials of concern appear to be copper and copper-base alloys, nickel and nickel-base alloys, aluminium and its alloys, and titanium and its alloys. Copper and copper-alloys are resistant primarily because they are noble. Selective leaching (dezincification, etc.) is a problem when an active metal is the alloying component. These alloys are suitable for marine or cavitation resistant applications. A tarnish resistant copper-aluminium-zinc alloy owes its resistance to the protective aluminium oxide film. Nickel and nickel-base superalloys are well-known in their commercial versions like Hasteloys, Inconels, etc. and hot corrosion and sulphidation resistance has been improved by the addition of chromium. A heat-treated nickel-titanium alloy may find application in extendable elements in spacecrafts. The importance of aluminium alloys in aerospace may have prompted the large number of works on their stress-corrosion aspects. The aluminium-magnesium type is particularly suited to marine applications. The aluminium cable industry is now well established. High cost of production was a deterent to the developments of titanium and its alloys inspite of relative abundance. They are now seeing rapid and steady growth primarily because of superior performance under severe environmental conditions.

...3.

Among the other systems finding mention are mostly rare metal alloys developed to meet particular needs inspite of their high cost. Chromium, niobium, molybdenum and tungsten find wide mention as favourable alloying additions. Magnesium and beryllium alloys have favourable strength-to-weight ratio, while tantalum and hafnium are considered for their superior corrosion resistance. Vanadium alloys find application as cladding materials for nuclear fuels and for resistance to mineral acids; diverse applications are found for the noble metals in industry. Zirconium alloys too, are important as cladding materials; a new one containing 10-12 per cent hafnium may satisfactorily replace silver for coinage. Cobalt-base superalloys are mentioned for their hot corrosion and sulphidation resistance.

Trends and Possibilities:

The general trends emerging are few, although the coverage in this review is representative rather than exhaustive. Superior performance of rare and exotic metals find consideration inspite of unfavourable cost factor, but established ones like the alloys of nickel, copper and aluminium and the newer titanium alloys are still the major ones. Material limitations should focus attention on design where all the following factors should be considered: structural, environmental, economic and aesthetic.

The collection of actual test data will perhaps continue in future for some time, in the absence of satisfactory fundamental approaches to predict the performance. Inspite of the complicacy of real systems, strides made in recent times on understanding the mechanism of simple (pure metal) systems might help develop this for the former. The Indian scene appears full of activities on corrosion research, but resources of strategic and common non-ferrous metals are either inadequate or poor. Import substitution, therefore, assumes importance while considering corrosion resistant metals and alloys to meet specific needs in practice.

/Ahmed: