Hardfacing with Cobalt-Base Alloys

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Introduction

Hardfacing alloys have assumed greater importance in the present day advancement in technological era. Modern technology has created operating and manufacturing conditions necessitating higher duty cycles on equipment and process. Maintenance and replacement are costly items—when converted to money in terms of downtime and production loss. With more exacting and demanding duty cycles on hardware, wear needs to be tackled in every possible way.

Wear is generally a surface phenomenon and takes place in the usage of a part or equipment. To reduce the wear, one of the obvious steps would be to find out an economical way to protect those surfaces of the metal parts that are subject to the common types of wear—i.e. abrasion, corrosion, impact and erosion. The most versatile and effective of the known methods is *Hardfacing*—also known as *Surfacing*.

What is Hardfacing

Hardfacing is a method of applying a wear-resistant metallic deposit to the surface of a metal part by welding. This is done by melting a thin layer of the base metal before or during the application of the hardfacing material. During welding, the surface of the base metal should be melted to a depth of only a few thousandths of an inch. The deposited alloy with the thin film of molten base metal, forms a strong metallurgical bond on cooling. The characteristics of the base metal and the hardfacting alloy are not changed by the hardfacing operation. The metal part of component once hardfaced with necessary properties to resist wear would keep the part in operation for longer duration.

Hardfacing is one of the oldest surface treatments known. The process did not find any commercial acceptance until 1920 when the oil industry began using the cobalt-base alloys to extend the life of drill bits. Since then onwards, hardfaced components have found wider acceptance by all leading industries, such as Mining, Earthmoving, Agriculture, Cement Mills, Steel Plants, Metal Fabrication, Chemical, Petro-chemical, Refineries, Aircraft and Automotive.

Selection of Hardfacing Alloy

To understand the wear-resistant materials fully and the basis for their selection, a knowledge of some of their metallurgical characteristics and general properties are necessary.

Most materials depend upon the formation of a hard transformation product to impart abrasion-resistant characteristics. Table—I below indicates the relative hardness of a number of constituents, some of which are found in wear-resistant materials.

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TABLE I

Relative Hardness of Hardfacing Constituents

	Knoop Hardness
Diamond	5500-6950
Chromium Boride	2900
Boron Carbide	2580-2900
Silicon Carbide (Gray)	2250-2760
Titanium Carbide	2350-2620
Aluminium Oxide (Alpha)	1860-2200
Tungsten Carbide	1570-2140
Chromium Carbide	1672-1960
Garnet	1240-1440
Cementite	940
Tool Steel (Hardened Rc-60)	730- 760
Martensite	390- 640
Austentite	412
Ferrite	154

However, hardness is not the only criterion for selection of a war-resistant material; factors such as corrosion and oxidation resistance, impact strength and hot hardness must also be considered.

The user has to ascertain the wear parameters which lead to the failure of the compenent. It may be due to one or cumulative effect of different wear parameters like impact, cold or hot abrasion, hot deformation, heat, metal to metal wear, corrosion, or erosion. It is observed that more often than not more than one wear factor is present. For example, one type of material may have superior abrasion resistance, but still fails in service as it can not stand up to severe impact, another may resist impact but failure may be for not withstanding corrosion.

After the choice of materials has been narrowed down to those suited to solve the wear problem, the kind of finished deposit that is required, must be considered—whether the hardfaced part should have smc oth deposit, free from hairline cracks or will a rough deposit do the job as well. Is a high polish required? Are frictional characteristics important as in 'bearings and seals? The answers to these questions will have an important bearing on the final selection. Finally the cost of hardfacing alloy must be considered. Initial cost of rod or electrode itself is only one of the many factors that determine the economy of using. The most important aspect is, how long the hardfaced component will last before it has to be repaired.

Types of Hardfacing Alloys

The hardfacing alloys, commonly used by industry, can be classified into four types namely, iron, nickel, cobalt-based alloys and tungsten carbide composites. The tungsten carbide materials are of a special nature and will not be discussed here. In other three types, the primary base elements are iron, nickel and cobalt. To these are added the major alloying elements like chromium, molybdenum and tungsten, sometimes as high as 30 to 35 percent. The minor alloying elements are carbon, silicon, manganese, vanadium and boron which run as high as 5% individually. All of these elements are not used in each alloy. However, many are used in various compositions and some alloys may contain as many as eight or nine of these elements in varying percentages.

Now let us examine the cobalt-base alloys in particular.

Cobalt-Base Alloys

Cobalt-base alloys, commonly referred to as "STELLITE" were originally developed by Elwood Haynes of Kokomo, Indiana, USA. Mr. Haynes was experimenting on different alloy compositions to find out a suitable alloy for flatware that would be less expensive than sterling silver and more durable than silver plate. Besides, the alloy had to possess resistance to corrosion from acids and other corrosive agents normally present in certain foods. One of these was an alloy consisting mostly of cobalt with additions of chromium and tungsten. On testing this particular alloy with lemon juice and other corrosive food, he found it would not tarnish but instead retained its surface brilliance much better than sterling silver. He named the alloy "STELLITE" from the Latin world "STELLA" meaning star.

As time went by, further developments took place and the other compositions were developed to provide varying degrees of hardness and toughness which gave birth to the cobalt-base hardfacing alloys.

The main constituents of cobalt-base alloys are cobalt, chromium and tungsten with varying amounts of carbon. The chromium content ranges from 25 to 32%. This element combines with carbon to form hard carbides that provide wear resistance. Chromium also provides corrosion resistance. The tungsten content ranges from 4 to 17 percent. This element also provides hardness, wear resistance and helps to resist the softening effect of heat. Cobalt, the major element, is the matrix that holds the chromium and tungsten carbides in suspension. It also provides the basic characteristics of this class of alloys—hot hardness.

The cobalt-base hardfacing alloys are commonly hardened by solid-solution strengthening and reinforced by carbide dispersion. This can be best understood when study is made of the equilibrium diagrams. Various types of carbides may be present in an alloy depending upon its compositions. Carbide stability depends upon both the temperature and the carbide composition relative to that of matrix. The carbide forming tendency varies from element to element, for example, chromium at normal working temperature is more powerful in this respect than tungsten.

Solid-solution strengthening is provided by tungsten and chromium. Since these elements also form carbides, their effectiveness as solid-solution hardeners depends upon both the amounts of these harder elements, carbon content and carbide composition.

The American Welding Society has classified this class of alloys broadly into three categories depending upon carbon and tungsten contents. This is given in Table-II at the end.

The alloys with lower tungsten and carbon content have excellent resistance to impact and thermal shock, but have less resistance to abrasion wear, whereas the alloys with higher tungsten and carbon percentages are harder and more abrasion resistant but have less resistance to impact and thermal shock.

The important characteristics of these alloys which give them an edge over other types of hardfacing alloys are discussed as follows :

The cobalt-base alloys or Stellite grades are solution hardening alloys i.e. they do not rely on heat treatment and its resultant change in metallurgical phases to develop properties. This is an important characteristic of cobalt-base alloys which therefore, can be heated to temperatures approaching their melting points and on cooling return unchanged to their original state, which is unlikely with iron-base alloys.

These alloys will retain their hardness at high red heat, remaining effectively hard at temperatures up to approx. 815°C. This is called 'Hot Hardness'. These alloys will not soften permanently, as will hardened steels but will return to their original hardness upon cooling.

The hot-hardness of cobalt-base hardfacing alloys has been described by many investigators and the graph given in Table III, at the end, indicates the relative hardness of the cobalt-base compositions with other hardfacing alloy groups and shows beyond doubt that the cobalt-base alloys are much superior above 650°C temperature except for tungsten carbide base materials.

These alloys resist oxidation and do not crumble or flake off when exposed to heat and air. Cobalt-base alloys are virtually unaffected by most corrosive media. They are exceptionally good for not only cold abrasion but also outstanding for metal to metal wear. Therefore, the alloys are considered the best all purpose hardfacing materials because they stand up under many conditions of wear such as heat, abrasion, corrosion, oxidation, friction and impact.

This takes us to the next subject viz. how these alloys are transferred to wearing surface of original parts or equipment.

Welding Process for Hardfacing

There are many processes available for depositing hardfacing materials to various types of base metals. It should be noted that all of these have one basic purpose and that is the actual application of the surfacing alloy. There are two basic groups into which all of them can be divided. These are *gas* and *arc*. Probably one of the oldest and most familiar to everyone is the standard oxyacetylene blowpipe which is used for welding as well as hardfacing. Bare rods are required with oxtacetylene process of deposition. The process is very well suited to small, intricate and complex configurations, though it offers lower rate of deposition whereas the arc welding process using coated electrodes offers faster rate of deposition and flexibility.

Applications

The industrial applications of cobalt-base hardfacing alloys are numerous and diversified. The applications cover steel plants, chemical plants (petroleum, fertilisers, plastics), power plants (thermal, hydroelectric, nuclear), cement mills, metal fabrication, sugar mills, paper mills and automotive etc. It is almost impossible to list the individual applications, However, to give an idea, some typical examples are, internal combustion engine valves, seat and disc of chemical and power plant, valves, trimming and forging dies, heavy duty shear blades and other cutting edges, pump arts, banbury mixer roters, oil expeller screws, cane cutting knife and bamboo chipper knife etc. etc.

By providing protection with the surfacing alloys, it has been possible to use cheaper metals for the body of the parts.

Conclusion

It has been discussed how hardfacing can be an effective tool in industry. Its applications extend from mining to nuclear power plants. The methods of application and material selection certainly affect the cost of utilisation of surfacing materials, however, the economics of maintenance free operation and continued productivity of equipment will often far out-weigh the original cost.

Among the various hardfacing alloys available today, Cobalt-base alloys find prominent place due to their metallurgical characteristics as explained earlier. The hardfacing alloys have been successfully used in conserving as well as increasing useful life of imported spare parts. There is still lot of scope to make effective use of these alloys for many more components. This will not only result in the efficient management of spare parts inventories but will lead to savings in foreign exchange.

TABLE II

Chemical Requirements of Cobalt-Base Surfacing Rods/Electrodes

Aws classification	*Carbon percent*	*Tungsten percent*	*Chromium percent*	*Cobalt percent*	*Total other Element percent max*
RCoCr-A	0.9 to 1.4	3.0 to 6.0	26.0 to 32.0	Remainder	10.50
RCoCr-B	1.2 to 1.7	7.0 to 9.5	26.0 to 32.0	Remainder	10.50
RCoCr-C	2.0 to 3.0	11.0 to 14.0	26.0 to 33.0	Remainder	10.50
ECoCr-A	0.7 to 1.4	3.0 to 6.0	25.0 to 32.0	Remainder	13.50
ECoCr-B	1.0 to 1.7	7.0 to 9.5	25.0 to 32.0	Remainder	13.50
ECoCr-C	1.75 to 3.00	11.0 to 14.0	25.0 to 33.0	Remainder	13.50

Notes : 1. R-Stands for Bare Rods, E-Stands for Electrodes

TABLE III

Relative Hot Hardness Properties of Hard Facing Alloys