HARDFACING CONSUMABLES AND THEIR CHARACTERISTICS FOR MINING AND MINERAL PROCESSING INDUSTRY

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In this third and last article the hardfacing consumables, their characteristics and selection is discussed.

GENERAL

For a user, the ideal hardfacing deposit is one that will resist all types of wear described earlier. In reality the formulation and selection of consumables is govemed by the predominant wear mode and by the economic considerations. These factors have led to the development and availability of a large number of hardfacing consumable compositions in a variety of forms.

Hardfacing consumable includes a wide range of alloys, ceramics, and combinations of these materials. Conventional hardfacing materials are normally classified as steels or low-alloy ferrous materials, chromium white irons or high alloy ferrous materials, carbides, nickel-based alloys, or cobalt-based alloys. A few copper-based alloys are sometimes used for hardfacing applications, but for the most mining and mineral processing applications, hardfacing alloys are either iron, nickel, or cobalt-based. The microstructure of hardfacing alloys consist generally of hard phase precipitates such as carbides, borides, or intermetallics bound in a softer iron, nickel, or cobalt-based alloy matrices.

Before selecting an appropriate hardfacing alloy for a given application it is necessary to carry out a careful analysis of all service conditions. A balance among wear properties, environmental resistance, weldability, and economy must be achieved. Balancing properties within each alloy system has led to the development of great many commercial hardfacing alloys. Most of these are marketed as proprietary alloys. It is not uncommon to find one alloy composition identified by many different commercial designations. This chapter describes characteristics, chemical compositions and forms of commercially available consumables.

CLASSIFICATION SYSTEM

Owing to the multiplicity of options, variety of chemical compositions and range of properties, many standard organizations have attempted to group and classify available hardfacing consumables. In North America, the American Welding Society classifications are mostly used.

American Welding Society (AWS) Classification System for Hardfacing Alloys

The American Welding Society (AWS) has developed a specification system for hardfacing rods and electrodes that uses an alphanumeric system with a prefix "E" for electrode and a "R" for bare wire or cast bare rods. Consumables designated "E" (electrode) carry current and are used in processes such as SMAW, SAW and GMAW. Rods do not normally carry current and are thus used in oxyacetylene, gas tungsten arc, and plasma arc welding processes. A series of letters in the identification system denote the chemical symbols for the major elements in the alloy. Thus, the designation RNiCr-A designates a bare rod (R), with nickel(Ni) and chromium(Cr) as the major elements comprising the hardfacing alloy. The "A" suffix denotes a particular range of chemical composition in a family of nickel/chromium alloys.

The AWS consumable designation system is only applicable to high speed steel, iron/chromium alloys, manganese steels, cobalt/chromium alloys, nickel/chromium/boron alloys, copper base alloys, and composites. Many other families of tool steels and alloy steels, are commercially available and will be listed in a later chapter. Fusion hardfacing alloys are also available in powder form for spray-and-fuse applications; however, these are not covered by the AWS designation system.

CONSUMABLE TYPES

Iron Based Alloys

Iron-based hardfacing alloys are the most widely used group and generally offer low cost and broad range of desirable properties for hardfacing equipment that is subjected to wear in digging, crushing, grinding and material transportation.

They are only partially covered by AWS, and because of their number they can best be classified by their suitability for resisting specific type of wear and their general microstructures. Most iron-based hardfacing alloys can be categorized into four groups; pearlitic steels, austenitic steels, martensitic steels, and high-alloy irons.

Pearlitic Steels : Are essentially carbon steels with minor adjustments in composition to achieve weldability. These alloys contain low carbon (0.45%) and limited amounts of other alloying elements, resulting in a pearlitic structure. Pearlitic steels are useful for buildup overlays, primarily to rebuild machinery parts back to size. Examples include shafts, rollers, and other parts in heavy machinery subjected to rolling, sliding, or impact loading. Typically this group of alloy has high impact resistance and moderate hardness (25-38HRC), as well as excellent weldability. Some usage of these alloys for repair welding and, buttering layers for crusher jaws, hammer mill hammers, etc,. These alloys are not covered by AWS classification system.

Table I(a) - Chemical compositions of some pearlitic hardfacing alloys

Grade	C (%)	Mn (%)	Si (%)	Cr (%)	Hardness (Rc)
AISI 1045	0.5	–	–	1.5	–
	0.5	0.8	0.3	1.0	–
	0.45	0.7	0.2	–	–
	0.4	1.5	0.6	4.0	38
	0.3	1.0	0.7	2.5	32
	0.2	1.0	0.5	1.5	–

Martensitic Steels : Alloys in this category are designed to form martensite during air cooling of weld deposits. As a result, they are often termed "self hardening" or "air hardening" and resemble tool steels with hardnesses in the range of 40-45HRC. Their carbon content can be up to 0.5%. Other elements such as molybdenum, tungsten, nickel (up to 3%), and chromium (up to 18%) are added to increase hardenability and strength and to promote the formation of martensite. Manganese and silicon are usually added to aid weldability.

The major hardfacing applications for these steels include unlubricated metal-to-metal rolling or sliding parts such as undercarriage parts of tractors. The impact resistance of martensitic steel is inferior to those of pearlitic or austenitic steels, but there is compensating increase in hardness and abrasion resistance. Typical applications are, earth scoops, dragline buckets, slurry pump housings, etc. Again these alloys are not covered by AWS classification system, however, they are covered by other designations and chemical compositions of some pearlitic and martensitic grades of hardfacing consumables are given in Table 1.

Table 1 (b) - Chemical compositions of some martensitic hardfacing alloys

Grade	C (%)	Mn (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)
E502	0.10	1.00	0.90	4.0-6.0	0.40	0.45-0.65
E430	0.10	1.00	0.90	15.0-18.0	0.60	
E410	0.12	1.00	0.90	11.0-13.5	0.60	
	0.7-1.5	2.0max	1.0max	5.5-9.5	2.0max	2.0max
	0.7-1.5	4.5max	1.0max	11-15	2.0max	2.0max

Austenitic Steels : These are medium-carbon steels containing sufficient manganese to cause retention of austenite at room temperature. The chemistry of these materials is comparable to the wrought and cast classes of work hardenable austenitic manganese steels. Thus they respond in a similar manner when used in high stress/impact mode with wear resistance increasing with severity of work hardening.

Most commonly available alloys in this category can be subdivided into low and high-chromium types. For most mining and mineral processing applications the favoured low chromium alloys usually contain up to 0.5%Cr and 12-15%Mn and some nickel and molybdenum. They are generally used to rebuild machinery parts subjected to high impact such as impact crusher, shovel lips in hard rock mining, crusher jaws, crusher rolls, mantles, ball mill liners, etc. They are not recommended for joining manganese steel parts due to the possibility of cracking.

The as-deposited hardness of these alloys is about 20HRC, however, the cold work can raise this hardness up to 50HRC depending on the degree of cold work. Austenitic manganese steels are not corrosion resistant and become embrittled at elevated temperatures. These alloys are also extremely difficult to machine and thus are used in as-deposited form. In the AWS classification system these are designated as EFeMn- or RFeMn and chemical compositions and as-deposited hardnesses of two popular grades are given in Table 2.

Table 2 - Chemical compositions of two AWS austenitic manganese hardfacing alloys

Grade	Ni (%)	Mo (%)	Si (%)	P (%)	As-Deposited Hardness (HRC)
EFeMn-A	2.75-6.0	-	1.3	0.03	20
EFeMn-B	–	0.6-1.4	0.3-1.3	-	20

(Other Elements: C-0.5-0.9, Mn-11-16, Cr-0.5)

High-Chromium Iron Alloys (AWS RFeCr-A and EFeCR-A)

The common feature of these alloys (popularly known as CrC hardfacings) is the presence of primary, eutectic and secondary chromium carbides (Cr7C3) which has a hardness exceeding 1500VPN which provide a high resistance to abrasion and erosion by softer silicates and quartz. The microstructure of these alloys also contain austenite, pearlitic, or martensitic depending on the alloy composition and processing. Their microhardness is in excess of 50HRC. Austenitic has lower strength and better toughness than pearlitic and martensite-bearing matrices. Martensitic grades have the highest hardness and resistance to deformation, but they are more prone to cracking. The chemical compositions of some of these alloys are given in Table 3.

Though these alloys contain more chromium than many stainless steels, they do not have comparable corrosion resistance due to their high carbon content. With as-deposited hardness in excess of 50HRC, chrome white irons are not easily machined and are used in the as-deposited condition. Most of them can be applied by oxyacetylene, FCAW, SAW and SMAW and some proprietary grades can be applied by almost anyone of the fusion welding processes.

Their good overall performance rating and relatively low cost, has resulted in this class becoming the most widely used hardfacing system.

Table 3 - Chemical composition of high chromium iron-based filler metals.

Grade	C (%)	Mn (%)	Si (%)	Cr (%)	Ni (%)
		Austenitic Type			
RFeCr-A1	3.7-5.0	4.0-8.0	1.0-2.5	27-32	–
RFeCr-A2	3.7-5.0	1.0max	0.5-2.0	27-32	2.5-4.5
		Martensitic Type			
N/A	2.5	1.0	0.7	26	–
N/A	4.0	1.5	2.0	30	–

Although these alloys have low impact toughness and tendency to spall, they are used in a wide variety of wear situations such as, low and high abrasion, and erosion. Typical applications are on mixer blades, screw conveyors, excavator blades, crushing mills, dipper teeth, pulverizers, scoop tram buckets, hammermill hammers and hopper liners,etc,.

Nickel Base Alloys (AWS RNiCr and ENiCr)

Many available nickel based alloys have proprietary compositions but the alloys covered by the AWS are given in Table 4. Most of these alloys are similar in composition, however, there is a small variation in carbon and boron content which is responsible for the change in the bulk hardness from about 35HRC in the A alloy to 60HRC in the C alloys. The matrix in these alloys is solid solution strengthened nickel and wear resistance is obtained by the presence of hard chromium boride (hardness=1300-1800 VPN) particles in the microstructure. They are not hardenable by heat treatment and thus are generally used as-deposited.

The physical properties of nickel based hardfacing alloys are similar to those of nickel and they have corrosion characteristics similar to other nickel-based alloys. They are not particularly chemical resistant, but they will not corrode in normal industrial environments and in outdoor services. These alloys retain their as-deposited hardness up to about 540°C. Nickel-based alloys are considered to be very brittle, however, they can be formed at room temperatures. Their melting points are 1090°C and they wet ferrous and other substrates better than most other nonferrous hardfacing alloys and thus are easy to apply. They are also more machinable than other hardfacing alloys of comparable hardnesses.

Nickel-based hardfacing alloys are available in coated electrode, bare wire or powder form and some proprietary versions are available as sweat-on pastes which can be applied to a surface with a variety of techniques, including paint brush and are then fused on the substrate with oxyacetylene welding process. As a family these alloys are suitable for abrasive wear and metal-to-metal wear, and are widely used on machine components that require finishing of hardfaced areas. These alloys have limited application in mining and mineral processing industry except in the hardfacing of cast irons.

Cobalt-Base Alloys (AWS RCoCr and ECoCr)

The cobalt-base alloys contain high chromium (>20%) which gives these alloys a high corrosion resistance. Thus these alloys are well established in industries that require heat-, corrosion-, and wear-resistant surfaces. There are many cobalt-based proprietary alloys such as Stellite and Tribaloy. The Tribaloy alloys are cobalt or nickel-based with molybdenum, silicon, and chromium as their major alloying elements. The cobalt-based alloys that are similar to Stellite alloys vary in carbon and tungsten content to produce alloys with different hardnesses. The matrix is essentially cobalt strengthened by chromium and tungsten. The compositions are balanced so that the bulk of the structure is hard, brittle layer (intermetallic compound) phase and have two layer hardness usually in the range of 50-60HRC. They are suitable for applications that require extreme chemical resistance.

The wear resistance of these alloys is enhanced by the formation of carbides. The high chromium content leads primarily to the formation of chromium carbides.

Table 4 - Chemical Compositions of some Nickel-Base Alloys

Grade	C (%)	Co (%)	Cr (%)	Fe (%)	Si (%)	B (%)	Typical Deposit Hardness
RNiCr-A	0.3-0.6	1.50	8.0-14.0	1.25-3.25	1.25-3.25	2.0-3.0	25-35
RNiCr-B	0.4-0.8	1.25	10.0-16.0	3.00-5.00	3.00-5.00	2.0-4.0	30-45
RNiCr-C	0.5-1.0	1.00	12.0-18.0	3.50-5.50	3.50-5.50	2.5-4.5	35-55

Table 5 - Chemical Compositions of some Cobalt-Base Alloys

Grade	C (%)	W (%)	Cr (%)	Mn (%)	Ni (%)	Mo (%)	Si (%)	Fe (%)	Typical Deposit Hardness
RCoCr-A	0.9-1.4	3.0-6.0	26-32	1.0	3.0	l.0	2.0	3.0	38-47
RCoCr-B	1.2-1.7	7.0-9.5	26-32	1.0	3.0	1.0	2.0	3.0	45-49
RCoCr-C	2.0-3.0	11.0-14.0	26-33	1.0	3.0	1.0	2.0	3.0	48-58

The abrasion resistance of the three basic AWS alloys increases with carbon content and hardness, however, the harder the alloy gets, more prone it becomes to cracking. Thus A alloys are widely used to produce wear-resistant areas on 300 series stainless steel chemical processing equipment. The cobalt-base hardfacings can maintain their room temperature properties up to about 650°C. These alloys are considered to be nonmachinable. Their high chromium content provides good oxidation resistance at temperatures up to 980°C. These alloys are expensive compared to other hardfacing alloys, thus they are best used where their unique properties are really needed. They are available in both rods and wire form. Again these alloys have limited applications in mining and mineral processing industry, however, some typical applications are knives, roasting oven flows, tongs for handling hot castings, etc,. Cobalt-based alloys provide very good resistance to high temperature (370°C) slurry erosion. Compositions of some Cobalt-base alloys are given in Table 5.

High Speed Filler Metals (AWS RFe5 and EFe5)

These steels are characterized by their high hardness and exceptional resistance to softening at elevated temperatures. This property enables machining to be carried out at higher speeds encountered in some mining operations such as drilling hard rocks. Originally they contained up to 20% tungsten to promote resistance to heat softening and to improve wear resistance by forming carbides. Most present day high speed steels contain tungsten and molybdenum for heat and wear resistance, chromium for hardenability and other elements such as vanadium or cobalt for additional wear resistance and heat resistance. The carbon content varies in the different high-speed alloys, but most contain about 1%. Two layer deposits of these alloys will have hardness in the range of 55 to 60RC. This hardness will come down by 10 points when heated to temperatures as high as 650°C. Although tool steels contain high alloy content, they are not considered to be corrosion, chemical or oxidation resistant. Typical applications of these alloys are in hardfacings of rock drills, bucket teeth and ripper teeth and chemical compositions of some popular alloys are given in Table 6.

Carbides

The volume of carbides (excluding chromium) used for hardfacing applications is relatively small compared to other common alloys. Lately there has been an increase in their use.

Their as-deposited structure consists of discrete extremely hard and abrasion resistant carbide particles surrounded by base metal matrices which provide toughness support. Historically only tungsten carbide grades have been used for hardfacing applications, however, recently carbides of other elements such as vanadium, titanium, molybdenum, tantalum, etc, have also performed satisfactorily. These consumables are available in the form of bare, tubular rods and coated electrodes. and are used with gas

Table 6 - Chemical compositions of high speed steel hardfacing alloys

AWS Grade	C (%)	W (%)	Mo (%)	V (%)
RFeS-A	0.7-1.0	5.0-7.0	4.0-6.0	1.0-2.5
RFeS-B	0.5-0.9	1.0-2.5	5.0-9.5	0.8-13

(Other Elements : Mn-0.5%,Cr-3.0-5.0%,Si-0.5%)

Table 7 - Suitability of hardfacing alloys for various wear modes

Wear Mode/ Hardfacing Consumable	Abrasion			Erosion	
	Low Stress	High Stress	Gouging	Solid Particle	Slurry
Iron Chrome	X	X	X	X	X
Nickel Chrome	X				X
Manganese Steel			X		
Cobalt-Based	X				X
Tool Steel	X			X	

tungsten arc and shielded metal arc welding processes.

The melting points of carbides are generally high and in many cases they tend to disintegrate prior to forming a molten weld pool. Therefore, the carbides themselves cannot be deposited by conventional welding techniques. To overcome this problem, carbides particles are usually inserted in a steel or alloy tube that is used as the welding consumable. Another process that is used for carbide hardfacing is the plasma spraying process (PSP) or D-gun. These are not truly welding processes as they do not create a metallurgical bond. The hardness of the deposits is about 60RC and these deposits are not machinable and hence must be used in the as-deposited conditions. Some typical applications of these materials for hardfacings are: rock drills, oil drills, sand mixer blades, bucket teeth (used for very hard rocks), ripper points, bulldozer end tips, etc.

The consumables covered by AWS are RWC-5/8, RWC-8/12, etc,.

SELECTION OF HARDFACING CONSUMABLES

Hardfacing alloy selection is guided primarily by wear (mechanism/ abrasiveness) and cost considerations. However, other manufacturing and environmental factors are involved such as base metal, deposition process, impact, corrosion, oxidation, and thermal requirements.

Wear Condition

Hardfacing is applied primarily to reduce wear loss, hence it is the single most important factor that govems the selection of the hardfacing alloy. Information regarding the various modes of wear operating in mining and mineral

Table 8 - Laboratory abrasion test data for some materials and hardfacing deposits (2)

Material	Abrasion Factor*	
	Low Stress	High Stress
Modified chromium iron hardfacing (5%C, 21%Cr, 8.5%Nb, 9%Mo, Rc-68	30	3.0
Tungsten carbide hardfacing (SMAW, 2.4%C 58%W, Rc-64	17	2.1
Chromium iron hardfacing (4.8%C, 23%Cr, 2%Mn, 1%Mo, 0.4%V, Rc-58	20	1.6
Chromium iron hardfacing (3.1%C, 14%Cr, 2%Mn, 1.5%Si, 0.5%Mo, Rc-53	4.6	0.95
Cast white iron-A (2.5%C, 25%Cr, Rc-61)	5.7	1.0
Cast white iron-B (3%C, 18%Cr, 1.5%Mo, 1%Ni, Rc-61)	11	1.4
Cast low-alloy steel (0.4%C, 1.9%Ni, 0.8%Cr, Rc-54	2.1	1.1
Martensitic steel hardfacing (0.8%C, 6%Cr, 1%Mn, 0.4%Si, Rc-50)	1.7	0.95
Manganese steel buildup (0.7%C, 14%Mn, 3%Cr, 0.3%Ni, Rb-97	2.1	1.0
Manganese steel buildup (0.1%C, 14%Mn, 10%Cr, l%Ni, Rb-91)	0.8	0.6
Mild steel bar (0.2%C, Rb-95	1.0	1.0

(*Abrasion Factor = weight loss of mild steel/weight loss of sample material)

Table 9 - Suitability of hardfacing alloys for various base metals

Base Metal to be hardfaced	Fe-Based Alloys (alloy content)		Co-N-Based Alloys	Tungsten Carbides
	<20%	>20%		
Carbon Steels				
0.10 - 0.35%C	Yes	Yes	Yes	Yes
0.35 - 1.0%C	Yes (1,2)	Yes (1,2)	Yes (1,2)	Yes (1,2)
Low Alloy Steels (0.3%C Max)	Yes	Yes	Yes	Yes
Low Hardenability Martensitic Stainless Steels (410, 403 type)	No	Yes (1,6)	Yes (1,6)	Yes (1,6)
High Hardenability Martensitic Stainless Steels (420, 440 type)	No	Yes (1,3,6)	Yes (1,3,6)	Yes (1,3,6)
Austenitic Stainless Steels (321Type)	No	Yes (3)	Yes (4)	Yes
Austenitic Stainless Steels (347 Type)	No	Yes (3)	Yes	Yes
All Other Austenitic Stainless Steels (300 Series)	No	Yes (3)	Yes	Yes
13% Mn Steel	Yes	Yes	Yes	Yes
Cast Irons	Yes	Yes	Yes	Yes
White Iron	No	No	No	No

1- Preheat required
2- Oxyacetylene process preferred
3- For limited applications only
4- Use a buttering layer of 347 type stainless steel
5- Use a buttering layer of Nickel
6- Postweld heat treatment required

processing was covered in earlier article and should be taken into consideration when selecting an alloy. Also, experience with hardfacing alloys for a particular application are a very valuable reference.

Table 7 lists the suitability of hardfacing alloys for various wear modes that are frequently encountered in the mining and mineral processing industry. Often more than one alloy appear to satisfy a property requirement. In such cases other factors such as life expectancy, cost and ease of deposition will play a major role in their selection. If longer life is required then a more expensive alloy can usually be justified. However, for maintenance and emergency repairs, the selection will be based primarily on the grades that are immediately available and secondarily on longer life. When a worn-out hardfacing has to be replaced with a new hardfacing then one should examine the performance of the previously used alloy. If the performance was satisfactory then the same alloy should be used, otherwise a new and improved alloy should be chosen.

Some laboratory abrasion test data on some hardfacings and base materials are provided in Table 8. These tests were carried out under high- and low-stress abrasion conditions. The interesting feature of these data is that under low-stress conditions, most materials performed better than mild steel (which was used as a reference material), however, under high stress abrasion conditions the performance of half of the materials was no better than the mild steel. Also under low stress conditions some materials were thirty times better than mild steel while under high abrasion conditions

Table 10 - The prices of various consumables in Canada in 1991

Consumable Type	Price ($/Kg)
Iron-based alloys	
Low-carbon steel buildup alloys	9.67
Austenitic manganese steels	9.95
Martensitic steels	11.30
High-chromium irons	17.40
Carbides	36.47
Cobalt-based alloys	90.00

Table 11 - Availability of consumables for various processes

	SMAW	GMAW	FCAW	Oxyfuel	Flame Spray
Buildup	X	X	X		X
Iron Chrome	X	X	X		
Nickel Chrome	X			X	X
Manganese Steel	X	X	X	X	
Cobalt-Based	X	X	X	X	X

Table 12 - Performance/cost indices for some hardfacing alloys (2)

Material	Performance/Cost Indices*	
	Low Stress Abrasion	High Stress Abrasion
Modified chromium iron hardfacing (5%C, 21%Cr, 8.5%Nb, 9%Mo, Rc-68	2.3	0.23
Tungsten carbide hardfacing (SMAW, 2.4%C 58%W, Rc-64	1.2	0.15
Chromium iron hardfacing (4.8%C, 23%Cr, 2%Mn, 1%Mo, 0.4%V, Rc-58	1.4	1.1
Chromium iron hardfacing (3.1%C, 14%Cr, 2%Mn, 1.5%Si, 0.5%Mo, Rc-53	3.8	0.78
Martensitic steel hardfacing (0.8%C, 6%Cr, 1 %Mn, 0.4%Si, Rc-50)	1.3	0.70
Manganese steel buildup (0.7%C, 14%Mn, 3%Cr, 0.3%Ni, Rb-97	2.3	1.1
Manganese steel buildup (0.1%C, 14%Mn, 10%Cr, 1%Ni, Rb-91)	0.4	0.3

the same material was only three times as good.

The impact resistance of hardfacing alloys decreases as the carbide content increases. As a result, in situations where a combination of impact and abrasion resistance is desired, a compromise between the two must be made. In applications where impact resistance is extremely important, austenitic manganese steels are used to build up worn parts.

Base Metal

The metallurgical compatibility between base metal has a significant influence on the choice of hardfacing consumable. In situations where the base metal and consumables are not metallurgically compatible, then it is necessary to apply a buttering layer before depositing the selected consumable. Table 9 shows the compatibility of various base materials and hardfacing consumables for a range of welding processes.

Costs

Consumable costs generally depend on form and amount and type of alloy content. Thus, iron-based pearlitic alloys are cheapest, while cobalt-based alloys appear to be most expensive. Prevailing prices of some consumables in Canada (in June 1991) are given in Table 10 for general comparison.

The deposition process plays an important role in the selection of consumables. It was reported earlier that some alloys are not available in all forms (bare rods, coated elec-

Table 13 - AWS hardfacing alloys and their applications in mining and mineral processing industry.

Application	AWS Hardfacing Alloy
Breaker Bars	FeMn
Bucket Teeth	FeMn
Bulldozer Blades	FeMn
Coal Conveyors	Ni- and Co
Coke Pusher	CoCr
Crusher Rolls	FeMn
Cutter teeth	WC
Drag chains	FeCr
Dragline Bucket Teeth	Fe5
Drill collars	WC
Gyratory Crusher	FeCr
Hammermill Hammers	FeMn, FeCr
Liners, Chutes and Hoppers	FeMn
Pug Mill Paddles	NiCr
Rock Crusher Rolls	CoCr
Rock drills	WC
Scoop tram buckets	FeCr

trodes, tubular rods, solid wires or powders). In addition some forms are only used in certain processes. Table 11 can be used as a guide for the availability of hardfacing consumables for a deposition process. Consumable price, however, should not be taken in isolation as a sole criterion when selecting hardfacing alloys and the performance / cost indices (Table 12) are more important. Finally some typical applications of some hardfacing alloys are given in Table 13.

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