Wearfacing

Weld Tech News

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WELD TECH NEWS is a newsletter for welders working primarily in maintenance and repair, each issue will contain useful information on materials (cast irons, steels, aluminum, copper alloys, etc.), welding products, welding techniques and safety. By collecting each issue, the reader will soon have a handy reference manual covering all aspects of welding, brazing and soldering for maintenance and repair.

WEARFACING

Wearfacing, or hardfacing, involves depositing a wear resistant surface by various welding techniques onto a base metal of different composition, in order to extend the working life of the piece being surfaced.

The surfacing alloy may be chosen for its resistance to abrasion, impact, galling, corrosion, or some combination of these and other factors. The base metal, on the other hand, may be chosen for economy, tensile strength or toughness.

Since the wearfacing alloy is applied only to specific wear areas, it can be an economical way to reclaim worn parts or to improve new parts. Properly used, wearfacing can increase the life of a part from two to twenty times. In fact, regular reconditioning of worn parts can extend their life almost indefinitely, eliminating most replacement costs.

There is no single “best” material for most jobs. The best surfacing alloy for a sand dredge auger, for example, would be a very bad choice for an air hammer bit. The best alloy for surfacing crusher rolls would vary, depending on the material being crushed and the size of the pieces.

There are hundreds of types of surfacing alloys, each with a different balance of properties. To make the right choice of alloy and application technique, we must first understand the different types of wear involved.

Types of Wear

Wear can be caused by impact, abrasion (grinding, erosion, gouging), galling, corrosion or heat.

Impact occurs when one object hits another. To resist impact, the alloy must be able to absorb energy through a combination of strength and ductility. If the alloy is brittle (strong, but not ductile), the impact will cause it to chip or crack. If the alloy is too soft (ductile, but not strong), the impact will cause it to deform.
Wearfacing WTN #4

Abrasion is wear caused by rubbing against a harder material. Grinding abrasion occurs when small, hard particles are rubbed under pressure, for example, when sand is caught in machinery, such as tractor rolls or idlers. Erosion involves low-stress scratching abrasion, as caused by plowing sandy soils, gritty particles in an airstream, or sand-bearing water flowing in a pipe. Gouging, involves high stresses on a large scale, usually associated with impact. Power shovels digging in rock fragments, or a crusher working on sharp rocks, would gouge grooves in the wearing surface, unless it were properly surfaced.

Galling can occur when metal parts slide against each other. Tiny areas on the surfaces weld together under pressure. As the movement continues, the weld is broken, tearing out a piece of material. Galling wear is worst when surfaces are rough, pressures are high, and the hardness of the two surfaces is approximately equal. Galling can be reduced by smoother surfaces, by introducing a film of lubricating oil or grease between the two surfaces, or by making one surface harder than the other (such as a cast iron shaft in a bronze bearing).

Corrosion involves an electro-chemical reaction on the metal surface. If a part is working in a corrosive environment, such as an acid, the part should have a surface that resists the particular type of corrosion involved.

Heat may influence the properties of a surfacing material by:

- changing grain structure (tempering or annealing);
- softening at elevated temperature; or
- accelerating corrosion.

Heat effects must be considered for materials used in a hot environment or in applications where friction generates local heat.

Since abrasion and impact are the main reasons for wearfacing, we will discuss them in more detail.

Abraision Versus Impact Resistance

The most abrasion-resistant alloys are very hard. However, many of the hardest materials (such as tungsten carbide, cast iron, or high carbon tool steel) are brittle and can be damaged by impact. The harder the surface, the less the impact resistance in most cases.

Metallurgical scientists have found ways to increase hardness at a minimum sacrifice in toughness or impact strength. However, there is always some tradeoff between these properties. Choosing a wearfacing alloy involves careful selection of the right balance between hardness and toughness, while considering economy and ease of application.
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Relief Checking

When a welded surface cools, it tries to contract. If the base metal is fairly rigid, it will resist, setting up tensile stresses in the surface alloy. Preheating the base metal before welding will reduce the difference in cooling contraction between the base metal and the overlay.

Many of the hard, brittle surfacing alloys are designed to “relief check”, creating many fine cracks that relieve tensile stresses, without otherwise damaging the deposit. The relief checks will minimize temperature distortion of the workpiece and reduce the possibility of underbead cracking and peel-off of the deposit. In general, these alloys should not be applied in more than one or two layers on flat surfaces and one layer on edges or corners. If applied too thick, the deposit may chip or spall off.

If the base metal is a highly-stressed, notch-sensitive steel, the relief checks can act as stress concentrators and cause cracks in the base metal. The best way to avoid this is to lay a strong, tough alloy layer between the base metal and the surface alloy. This buffer layer can also be used to build up a very worn part to approximately the right dimension before applying the final surfacing layer of abrasion-resistant material.

If the base metal is relatively soft, mild steel, it may deform under load, causing cracks in the surface alloy. A buffer layer of high strength steel can be laid on the base metal to give the surface alloy a sufficiently rigid support.
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Wearfacing Materials

The materials used in wearfacing fall into several groups:

- **tungsten carbides**, crushed to various size grades and held in a steel or nickel matrix. The tungsten particles are the hardest material widely used for wearfacing. The overall performance depends on the type of matrix and the application method.

- **chromium carbides** are slightly less hard than tungsten carbides, but more suited in some applications.

- **semi-austenitic steels** are high carbon alloys containing chromium and other elements. They have general impact resistance and work harden under impact to give them good abrasion resistance.

- **manganese steels** are tougher than the semi-austenitic steels, but have less abrasion resistance. They have excellent work hardening properties and are widely used as a base metal and underlayment for construction and railroad equipment subject to impact.

- **chromium nickel steels** have excellent corrosion resistance, strength and toughness. Some of these have work hardening properties.

- **high nickel alloy powders** have excellent properties for wearfacing using a spray metallizing torch.

Methods of Applying Wearfacing

Arc welding is the fastest way to apply large deposits and can be used with a wide range of alloys. The electric arc is very hot - about 10,500°F (5800°C) for a coated stick electrode - but the heat is brief and localized, so that arc welding actually puts less total heat into the workpiece than gas brazing. However, the arc’s concentrated heat can cause stresses in the base metal in some applications, unless recommended preheats are used.

An electric arc will easily melt tungsten carbide crystals, causing them to alloy with other materials and reducing their hardness somewhat.

An oxygen-acetylene flame, often used for gas brazing will have a maximum temperature of 5600°F (3100°C). Although this is much cooler than an arc, the flame must be applied for a longer period. Therefore, the total heat input to a brazed workpiece is higher than for a similar arc welded piece. Gas brazing is more likely to damage heat-treated workpieces and generally should not be used on austenitic manganese steels.

Although gas brazing is slower, it is generally easier to control the deposit shape and thickness.

Sharp, hard, unmelted tungsten carbide crystals in a strong nickel or bronze matrix can be applied by brazing to produce an excellent wearfacing for many applications.

Spray metallizing is the slowest method in most cases, but allows great control, excellent surface smoothness and regularity, and thick or very thin deposits, as needed.
A WEARFACING GUIDE FOR ARC WELDERS

Wearfacing, or hardfacing, is one of the least understood branches of welding. Choosing the right alloy and the right technique for a particular application can be confusing.

To help the maintenance welder deal with these problems, Rockmount wearfacing engineers have developed a group of specialized alloys that will cover almost every wearfacing requirement. The arc welding alloys in this group and some "tricks of the trade" are described below.

Before selecting a material, the welder must determine the types of wear involved (impact, grinding, erosion, etc.), the thickness of material needed and, where possible, the kind of base metal.

In general, the hardest wearfacing alloys should only be applied one or two passes deep. Otherwise, cooling and working stresses will cause them to chip or spall off. Where a deep buildup is required, the welder can apply a tough, ductile underlayer to bring the level close to the final dimension and then finish off with a hard top coat.

Hardness is measured on many different scales. The most common scales used for wearfacing are Brinell (abbreviated “B”), and Rockwell B and C scales (abbreviated “Rb” and “Rc”). In each scale, the higher number indicates a harder material. Following is an approximate comparison of these scales:

<table>
<thead>
<tr>
<th>Brinell</th>
<th>150</th>
<th>240</th>
<th>283</th>
<th>484</th>
<th>614</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwell B</td>
<td>80</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rockwell C</td>
<td>-</td>
<td>22</td>
<td>30</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

Some alloys "work harden" as impact loads refine the surface grain structure to increase hardness. As the surface slowly wears away, continued impact hardens the next layer. However, if the wear is mostly from abrasion with low impact, as in a sand dredge, the impact force will not be enough to harden the surface. In these cases, an alloy with a high initial hardness should be applied.

When applying very hard alloys, preheating the workpiece will reduce the cooling stresses after welding. The process of welding on a buffer layer under the top layer will add some preheat to the piece.

Following are the descriptions of the principal arc welding alloys for wearfacing, with some comments on how they can be used most effectively.

**Apollo-A** can be used for buildup and wearfacing. It combines high strength (135,000 psi) and high ductility (30%) in a special manganese-steel alloy with unusual impact resistance, making Apollo-A especially useful for construction machinery and railroad applications, such as buckets, crushers, rails,
Wearfacing WTN #4

frogs and crossovers. It has good initial hardness (185 Brinell), which improves with impact as it workhardens to 550 B.

Apollo-A works well by itself where high impact loads, such as falling hard rock, would damage a harder, more brittle alloy. It can be cut with a torch and machined with carbide tools. It can be applied in multiple passes to any thickness, which makes it especially useful for building up extremely worn parts. In cases where very high abrasion resistance is needed, Apollo-A makes a good buffer layer to build up the workpiece to near the final dimension. Then, a final layer can be added (one or two passes) of a harder alloy, such as Olympia-A or B or Zeta-B or C (see below).

Apollo-B is designed for compatibility with dissimilar steels, with good strength (105,000 psi) and superior ductility (37%). It has almost as much impact resistance as Apollo-A and similar hardness (20 Rc as deposited, which can be workhardened to 40-45 Rc). In addition, the special alloy chemistry of Apollo-B gives it good corrosion resistance and hot hardness to 1000°F (540°C). Apollo-B can be used by itself in applications such as joining wedge bars to dipper teeth, or for repairing crusher rolls, or for building up worn surfaces on manganese or carbon steels. Like Apollo-A, Apollo-B is also excellent as a buffer layer under a harder, more abrasion-resistant final layer.

Olympia-A is an excellent, general-purpose wearfacing for construction equipment, with a deposited hardness of 52-54 Rc, which workhardens to 60 Rc. The combination of abrasion resistance, impact resistance and the ability to be run out-of-position makes Olympia-A a widely-used, general purpose surfacing material for crusher rolls, hammers, cutters, shovel buckets, pump impellers, conveyer wear surfaces and similar applications. It can be built up to a total thickness of 1/4 inch.

Alloys like Olympia-A are often applied in dot or row patterns, depending on the type of service.

For work in hard rock, for example, the rows are run parallel to the material flow, so the rocks can slide or skip easily along the top of the hardfacing. For work in sand or dirt, the rows are run at right angles to the material flow, or in a waffle pattern, so that the sand packs in between the rows, protecting the base metal beneath from excessive abrasion. The spacing between the rows will vary depending on the material handled, but one inch between rows is often used. In mixed applications, involving both rock and sand, a waffle or diamond pattern is often used, as a compromise.
WEARFACING APPLICATION TECHNIQUES

Bucket teeth should be wearfaced along the top and sides, preferably before being placed in service. Do not wearface the bottom. Wear along the bottom will constantly sharpen the teeth, reducing the digging effort. Wearfacing in this way often increases service life by 300%.

When a wearfaced part has worn and requires rebuilding, it is generally better to remove any remaining wearfacing with a gouging electrode, such as Electra, before applying new buildup and wearfacing layers. Where this is not practical, make sure that a ductile buffer layer, such as Apollo-A, is added between the old and new hard layers to prevent cracking and spalling at the top layers.
Wearfacing WTN #4

Occasionally, a welder will need to combine a thick buildup with very high abrasion resistance. In such cases, it is possible to start with a buffer layer of Apollo-A, top it with a layer of Olympia-A, then add more layers of Apollo-A and Olympia-A in turn.

Olympia-B contains silicon and chrome carbides and has an initial hardness of 66 Rc when applied to the maximum of two passes. It has very high abrasion resistance, but only mild impact resistance, making it ideal for dredge pump impellers, and housings, screw conveyors, plow shoes, mixer chutes and blades, and similar applications.

In one application, Olympia-B applied to the flights of a screw-type sand conveyor extended the time between wearfacings from once-per-week to once-per-month. In another application, the wear life of an expulsion fan in a sand classifier was increased over 500%.

When applying a very hard alloy like Olympia-B, it is advisable to preheat the work piece, especially for high alloy steels or cast iron. Stress relieving cracks will appear in the Olympia-B, which will not affect the wear resistance, but will reduce any tendency to spall off.

Olympia-C is a special, high-temperature, cobalt-based alloy, designed to replace satellite-type facings in applications exposed to heat, impact and corrosion. Olympia-C is ideal for forging dies, punches, valves, valve seats and all hot work tools. It has a tensile strength of 118,000 psi and a compressive strength of 210,000 psi, with a hardness of 43 Rc (workhardens to 49Rc), and high impact resistance. It remains hard at 1200°F (650°C) and can withstand temperatures up to 1950°F (1065°C).

Zeta-B and Zeta-C are two types of extra large, low amperage, fast depositing electrodes. A 1/2" electrode can be run as low as 150 amps, giving minimum weld metal dilution. A welder can easily deposit 10 pounds per hour of these high-yield electrodes, significantly reducing the labor cost of hardfacing. Both Zetas normally relief check and should be limited to two layers.

Zeta-B produces chrome carbides in an austenitic iron manganese matrix, with a hardness of 50-55 Rc, good abrasion resistance and medium to heavy impact resistance. It is suitable for dragline buckets, shovel teeth, pump liners and similar applications.

Zeta-C produces chrome carbides in a mixed austenitic-martensitic matrix of iron, manganese, vanadium and molybdenum. The hardness is 58-62 Rc, with only slightly less impact resistance than Zeta-B. In one case, where Zeta-C was used on the auger of a brick company’s clay pugmill, the service time was increased 600% over the hardfacing formerly used! After the first trial, this company quickly ordered its six other plants to convert to using Zeta-C.

Omega-N produces an unusually smooth, low-friction deposit with a hardness of 60-62 Rc and good impact resistance. It lays down fast and easily in all positions. Omega-N is widely used in mines and quarries for rock crushers and pulverizing mills subjected to severe abrasion combined with high impact. In these applications, it often outlasts competitive wearfacing materials by 200-300%.
**Wearfacing WTN #4**

*Olympia Wear Plates* are 3" x 6" x 3/16" hardened plates (60 Rc) for quickly resurfacing large areas of chutes, shovels, mixer blades, etc. The plates are plug welded in place through the center hole, using *Apollo-A*, and can be additionally secured by welding around the circumference.

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