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Hardfacing: Your ally in improving size reduction efficiency

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The equipment that crushes or grinds your dry bulk material takes a real beating, often leading to equipment downtime and high replacement and refurbishment costs. Applying hardfacing via welding to your size reduction equipment surfaces can improve your operation's efficiency by lengthening the equipment's service life and keeping your maintenance costs under control. This article discusses abrasive and impact wear in size reduction equipment and how to choose and apply a hardfacing alloy.

When several types of wear can affect bulk solids processing equipment, size reduction equipment is most often affected by either abrasive wear or impact wear - and often by both. The wear can lead to frequent replacement or refurbishment of equipment surfaces and components, such as liners, hammers, and crusher rolls, increasing your operation's downtime and maintenance costs.

You can't entirely eliminate these wear losses, but you can minimize them by properly selecting and applying specialized welding alloys, called *hardfacing, to* your equipment's critical wear areas. By the American Welding Society's definition, hardfacing is a layer of surfacing metal that increases a metal surface's resistance to various types of wear, including abrasion and impact.

However, identifying the right hardfacing alloy (which is typically sold in the form of welding rods or wires) and welding procedure for your equipment is a challenge because very little formal training is available for this. Because hardfacing is not an engineering discipline, many of those responsible for choosing and applying hardfacing have learned from other practitioners or by trial and error. In fact, the welding operators who typically apply hardfacing are taught to join two materials together, not how to specify a hardfacing alloy or apply it. As a result, many equipment users are reluctant to try new hardfacing alloys or application methods and this has slowed down the fight against equipment wear.

About abrasive and impact wear

Abrasive wear and impact wear can be categorized by the effect each has on a surface. Abrasive wear, the most common, occurs when particles grind or gouge away a surface. Impact wear occurs when particles strike the surface and cause it to deform plastically -and, sometimes, fracture away.

The principal wear modes in size reduction equipment are high-stress abrasion, gouging abrasion, and impact wear. The equipment surfaces generally wear from a combination of these modes, although one mode is usually the chief culprit in any given application.

High-stress abrasion. In high-stress abrasion the abrasive particles being crushed in the size reduction equipment impart a grinding action to the equipment surface. This is sometimes called *grinding wear* or *three-body wear* (in which the three bodies are the particle, the moving equipment component - such as a stripper bar or pulverizing hammer -and the equipment wall). High-stress abrasion causes particles to gouge the surface and remove small metal slivers. This action also causes the abrasive particles to fracture under pressure, as shown in Figure 1, exposing new and sharper cutting surfaces on each particle and further accelerating the equipment wear. The pressure by the particles is so great that the equipment surface at the wear scar also plastically deforms. This fatigues the surface and can cause it to wear more rapidly.

High-stress abrasion typically affects crusher stripper bars, impact crusher rotors, gyratory crusher cones and mantles, roll crusher rolls, clinker grinding rolls, pulverizing hammers, and pulverizer rolls and rings.

Gouging abrasion. In gouging abrasion, the impact and compressive loading of the abrasive particles remove large slivers or chunks from the equipment surface, as shown in Figure 2. The gouging causes severe plastic deformation around the wear scar, but the abrasive particles usually don't fracture. If the equipment surface can't absorb the stress of plastic deformation, the surface becomes fatigued and fractures away, accelerating wear.

Gouging abrasion typically affects shredding hammers, cage mill parts, and gyratory crusher cross heads, as well as common size reduction components such as liners and liner plates, grizzly bars, and screen grates.

Impact wear. Impact wear occurs when localized compressive loading from rocks or other large particles causes an equipment surface to plastically deform to a greater degree than is possible with high-stress or gouging abrasion. If the surface isn't sufficiently ductile, it will fracture away (called spalling), as shown in Figure 3, instead of deforming. Impact wear typically affects crusher jaws, impactor bars, and hammermill hammers.

Choosing a hardfacing alloy

Avoiding common pitfalls. Choosing a hardfacing alloy requires carefully assessing the kind of wear your size reduction equipment receives and comparing the characteristics of available alloys. Don't make the common mistake of choosing a hardfacing alloy based on its price per pound and ease of welding rather than the overall cost savings it can provide in your operation. And don't assume that two alloys with the same hardness rating will wear the same -they won't.

You can demonstrate this for yourself by heat-treating a piece of AISI (American Iron and Steel Institute) 4140 steel and apiece of AISI D2 tool steel to a hardness of 58 Rockwell c-scale (Rc), then applying equal pressure to each piece with a hand grinder. You'll see that the tool steel will wear considerably less. This doesn't mean that it's "better" than the AISI 4140 steel - in fact, it only proves that a material's microstructure and alloy content have a greater influence on abrasive wear resistance than hardness alone.

If you take the same two pieces of steel and subject them to impact, the AISI D2 tool steel might chip away rather than absorb the impact energy as the AISI 4140 steel would. While the two steels have the same hardness, the AISI 4140 steel is tougher (that is, it resists impact better because it plastically deforms rather than fracturing away) and the AISI D2 tool steel is comparatively more brittle. For this reason, the following information on selecting a hardfacing alloy is based on alloy toughness and brittleness rather than hardness alone.

Considering wear modes. While most wear in size reduction equipment results from a combination of wear modes, you should select a hardfacing alloy (or combination of alloys) to combat the most significant wear mode for your equipment. This decision is complicated because, in a given application, the balance of abrasive wear and impact wear affecting the equipment is unique, and the ideal hardfacing alloy must be able to adequately resist the abrasive wear but also be tough enough to resist fracturing as it plastically deforms due to impact wear. As a result, no one alloy is the right choice for all applications.

Figure 4 shows relative impact and abrasive wear resistance for hardfacing alloys commonly used in size reduction equipment, ranging from very tough, ductile alloys that resist impact wear, to less tough but harder alloys that resist abrasive wear. Hardfacing alloys that resist impact

Figure 1

High-stress abrasion in roll crusher

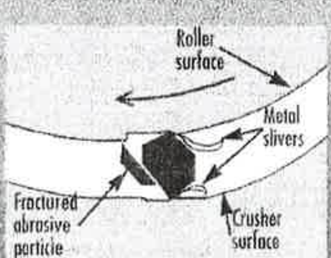


Figure 2

Gouging abrasion

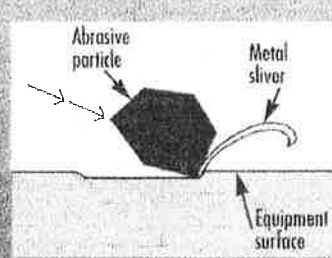
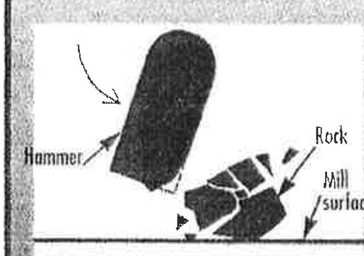


Figure 3

Impact wear in hammermill



wear (alloys 1 through 3 on Figure 4) consist of manganese and other materials that have strong work-hardening properties after they're welded on an equipment surface.

These have a hardness of 15 to 20 Rc as welded. Then, as the size reduction equipment operates, impact loadingcauses the hardfacing to plastically deform, changing its microstructure and causing its surface to work-harden to 50 to 55 Rc in proportion to the load.

Below the surface, the alloy remains tough and ductile. As the surface wears away, new hardfacing metal is exposed and the work hardening process continues. All hardfacing alloys that resist abrasive wear (alloys 4 through 7) consist of hard microconstituents - usually carbides -held in place by a tough weld matrix consisting

Manganese (noncarbide-containing) work-hardening alloys

Key:

Relative resistance to impact wear

Relative resistance to abrasive wear

1. Low-chromium manganese (14 to 16 percent manganese, 3 to 4 percent chromium, 2 to 3 percent nickel, 0.9 to 1.2 porcent carbon, balance iron; typical as-welded hardness of 15 to 20 Rc and work-hardened to 50 to 55 Rc; 1-inch maximum thickness)

2. High-chromium manganese (14 to 16 percent manganese, 14 to 16 percent chromium, 0.3 to 0.4 percent carbon, balance iron; typical as-welded hardness of 15 to 20 Rc and work-hardened to 50 to 55 Rc; 1 -inch maximum thickness)

3. High-manganese (13 to 20 percent manganese, 3 to 5 percent chromium, 1 to 2 percent nickel, 1 to 1.5 percent carbon, balance iron; Typical as-welded hardness of 15 to 20 Rc and work-hardened to 50 to 55 Rc; 1-inch maximum thickness)

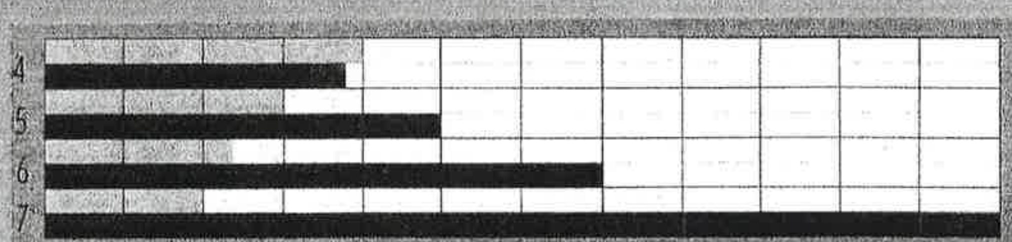
Carbide-containing alloys

4. Chromium carbide (low-alloy type) (9 to 12 percent chromium, 2 to 3 percent carbon, 1 to 3 percent manganese, balance iron; typical as-welded hardness of 40 to 45 Rc; maximum thickness 3/4 inch or less)

5. Chromium carbide (medium-alloy type) (10 to 15 percent chromium, 3 to 4 percent carbon, 1 to 3 percent manganese, balance iron; typical as-welded hardness of 45 to 50 Rc; maximum thickness 1/2 inch or less)

6. Chromium carbide (high-alloy type) (24 to 28 percent chromium, 4 to 5 percent carbon, 1 to 3 percent manganese, balance iron; typical as-welded hardness of 55 to 60 Rc; maximum thickness 3/8 inch or less)

7. Multicarbide (20 to 22 percent chromium, 5 to 6 percent molybdenum, 5 to 6 percent niobium, 5 to 6 percent carbon, balance iron; typical as-welded hardness of 60 to 65Rc; maximum thickness; 1/4 inch or less)



[1]Note.-The multicarbide alloy's resistance to abrasive wear is more than double that illustrated here.

of materials such as chromium, carbon, and manganese. For example, if your equipment is subject to severe abrasion, you can choose a multi-carbide alloy (alloy 7) that has a high carbide concentration and a hard weld matrix of 60 to 65 Rc. Or if your equipment is subject to abrasive wear with impact wear, you can choose a tough alloy like chromium carbide medium-alloy type (alloy 5) with a low concentration of carbides and a softer weld matrix of 45 to 50 Rc.

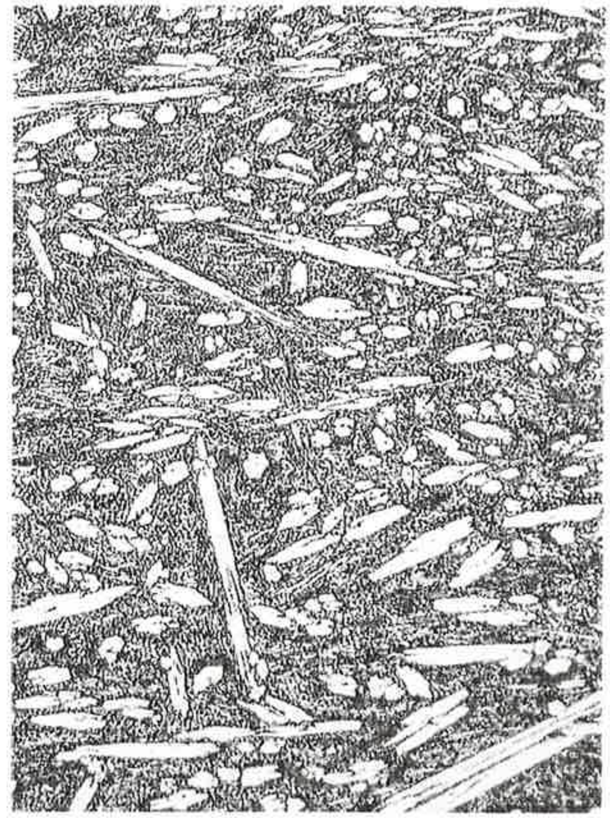
Alloys can be applied in various thicknesses, depending on the alloy type. Figure 4 lists the thickness limits for each hardfacing alloy. A surface subject to severe impact wear is typically built up with a thick layer of manganese alloy because this alloy can be applied in up to 1-inch thickness without cracking. This makes a manganese alloy ideal for an equipment surface that requires a heavy hardfacing buildup without a risk of cracking or spalling. A low-to medium-alloy carbide-containing alloy can be applied in one or two thin layers over a thick layer of manganese alloy to provide additional abrasion resistance. To provide maximum impact wear resistance, you can use these manganese alloys alone, but you'll be sacrificing some abrasion resistance.

Testing. Because conditions like the type of your size reduction equipment and the hardness of the material you'll be reducing in the equipment are unique to your application, choosing a hardfacing alloy requires testing. The tests involve applying a hardfacing alloy to one or two components or small surface areas in the equipment and running material through it, then checking the hardfacing areas for wear.

You need to run the test on a series of alloys to ensure that you find the right alloy for your application. To begin the tests, apply an alloy that's inherently tougher and less brittle (one of the alloys 1 through 3 in Figure 4) to your equipment. If the alloy doesn't fracture off but doesn't last as long as you'd like, try the alloy with the next higher number. But if the alloy you test is too brittle, it will fracture off instead of wearing off. In this case, test the alloy one or two numbers lower.

Applying hardfacing

At least 50 percent of the success of any hardfacing application depends on the welding operator. Applying hardfacing is a blend of welding science and art; there are no formal specifications for the process. Unless the welding operator in your plant has been specifically trained to weld hardfacing, you may discover that the hardfacing doesn't last as long as you'd hoped or provide the wear resistance you'd counted on. For best results, make sure that your welding operator is properly trained in how to apply hardfacing to your equipment surfaces and components. Various technical schools and, in some cases, hardfacing alloy suppliers can provide this training.



Hardfacing alloys consist of several materials. This micrograph shows a chromium carbide high-alloy type magnified more than 50 times.

For further reading

Find more information on abrasion resistance, hardness ratings, and size reduction equipment in articles listed under "Abrasion resistance" and "Size reduction" in *Powder and Bulk Engineering's* comprehensive "Index to articles" (in the December 1999 issue and at www. Powderbulk.com).

An article by the author in an upcoming issue will discuss hardfacing for other types of bulk solids handling and processing equipment. More information on how to choose a hardfacing alloy can be found at his company's Web site, www.postle.com

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