



American Welding Society

The Practical Reference Guide for

Hardfacing



THE PRACTICAL REFERENCE GUIDE for HARDFACING

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EDITOR NOTES

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BASIC SAFETY PRECAUTIONS

Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpiece should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Avoid breathing the air in the fume plume directly above the arc. Do not weld in a confined area without a ventilation system. Use point-of-welding fume removal when welding galvanized steel, zinc, lead, cadmium, chromium, manganese, brass, or bronze. Do not weld on piping or containers that have held hazardous materials unless the containers have been inerted properly.

Compressed Gas Cylinders. Keep caps on cylinders when not in use. Make sure that gas cylinders are chained to a wall or other structural support. Do not weld on cylinders.

Radiation. Arc welding may produce ultraviolet, infrared, or light radiation. Always wear protective clothing and eye protection to protect the skin and eyes from radiation. Shield others from light radiation from your welding operation.

Ventilation During Welding. Five major factors govern the quantity of fume to which welders and welding operators are exposed during welding:

- (1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)
- (2) Number of welders and welding operators working in that space
- (3) Rate of evolution of fumes, gases, or dust, according to the materials and processes involved
- (4) The proximity of the welder or welding operator to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which he is working
- (5) The ventilation provided to the space in which the welding is done

Refer to the section entitled, "Ventilation" in American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* for a discussion on the ventilation that is required during welding.

Special Precautions. In the following conditions when using thermal spraying:

- (1) The main source of hazard during the thermal spraying operation is the intense heat produced by the spray gun.
- (2) The heat combines with other factors to produce additional secondary hazards. These include: dust and mist; radiated light, infrared and ultraviolet; and high intensity noise.
- (3) Grit blasting, performed for surface preparation, provides hazardous conditions: high velocity air and grit stream, dust from blast impact, and loud noise.

Caution must be exercised in protective clothing, safety glasses and shoes, and eye and ear protection. AWS recommends a personal copy of "Arc Welding Safely," "Fire Safety in Welding and Cutting," "Safety in Welding, Cutting and Allied Processes," "Thermal Spray Manual," "Arc Welding and Cutting Noise," and "Lens Shade Selector." See Ordering Information under "Other Publications Available from AWS."

Introduction

Hardfacing is one category from the family of surfacing processes. Surfacing is defined in AWS A3.0, *Standard Welding Terms and Definitions*, as “The application by welding, brazing, or thermal spraying, of a layer, or layers, of material to a surface to obtain desired properties or dimensions, as opposed to making a joint.” The surfacing processes may be grouped as surface cladding, buildup, buttering, and hardfacing. These processes are defined as follows:

Cladding. A surfacing variation that deposits or applies surfacing material usually to improve corrosion or heat resistance.

Buildup. A surfacing variation in which surfacing material is deposited to achieve the required dimensions.

Buttering. A surfacing variation that deposits surfacing metal on one or more surfaces to provide metallurgically compatible weld metal for the subsequent completion of the weld.

Hardfacing. A surfacing variation in which surfacing material is deposited to reduce wear. (A non-standard term for hardfacing is *hard surfacing*.)

Hardfacing Applications

In hardfacing applications, a layer of surfacing metal is applied to reduce wear by increasing the resistance of a metal surface to abrasion, impact, erosion, galling, or cavitation. As with cladding, the strength of hardfacing is not considered in the design of the component (see Table 1).

In addition to the characteristics of the surfacing material and base metal, other important considerations when choosing hardfacing applications are:

- (1) Geometry of the part to be surfaced
- (2) Cost of the material and labor
- (3) Techniques to prevent cracks in the surfacing or application-generated cracks
- (4) Techniques to minimize distortion from the thermal stresses of welding
- (5) Quality of the deposit

Table 1. Common Surfacing Processes and Materials

Process	Mode of Application	Surfacing Metal Forms
Oxyfuel gas (OFW)	Manual or semiautomatic	Powder and bare cast and tubular rods
Shielded metal arc (SMAW)	Manual	Covered electrodes, solid cast electrodes, and tubular electrodes
Flux cored arc (FCAW)	Semiautomatic or automatic	Composite electrode of metallic sheath and powder core
Gas metal arc (GMAW)	Semiautomatic or automatic	Bare solid and tubular electrodes
Submerged arc (SAW)	Automatic	Bare solid and tubular wires and strip
Gas tungsten arc (GTAW)	Manual or automatic	Powder, bare solid and tubular wires, and bare cast rods
Plasma arc (PAW)	Automatic	Powder and bare and tubular wires
Thermal Spray Processes		
Flame spraying (FLSP)	Semiautomatic or automatic	Powder and bare and tubular wires
Plasma spraying (PSP)	Semiautomatic or automatic	Powder
Arc spraying (ASP)	Semiautomatic or automatic	Bare and tubular wires
High-velocity flame	Semiautomatic or automatic	Powder

Hardfacing Properties

Properties of the hardfacing process are as follows:

Hardness

- Macrohardness (gross hardness)
- Microhardness (hardness of individual constituents in a heterogeneous structure)
- Hot hardness (resistance to the weakening effect of service at elevated temperature during short time loading)
- Creep resistance (resistance to plastic deformation when loaded at elevated temperatures for relatively long periods of time)

Abrasion Resistance

- Under low stress (scratching wear)
- Under high stress (grinding)
- Under high stress and impact (gouging)

Impact Resistance

- Resistance to plastic deformation under repeated impact loading (related to yield strength and fatigue strength)
- Resistance to cracking under impact loading (related to ductility but including work-hardening considerations)

Heat Resistance

- Resistance to tempering (softening with time at temperature)
- Retention of strength when hot (including hot hardness)
- Creep resistance (time factor added to hot strength)
- Resistance to oxidation or corrosion by hot gases

Corrosion Resistance

Metal-to-Metal Resistance

- Friction coefficients (relative ease of sliding)
- Galling tendency (localized welding)
- Surface films (oxide layers)
- Lubricity (slipperiness)
- Plasticity (ability to deform)

Erosive Wear Resistance

- Under high-angle solid particle impingement
- Under low-angle solid particle impingement
- Under liquid droplet erosion
- Under cavitation conditions

Hardfacing Advantages

When compared with other surfacing processes, hardfacing has the following advantages:

- (1) Additional resistance to wear or corrosion exactly where it is needed
- (2) Ready application in the field
- (3) Economical use of expensive alloys
- (4) A hard surface layer to resist wear that is supported by a tough substrate to carry the load

Selection of Hardfacing Materials

Factors to be identified for selection of surfacing materials (see Tables 2–8) includes:

- The type of abrasive to be encountered and its characteristics (hardness, sharpness, particle size, and toughness)
- The amount of impact to be encountered
- The amount of support provided to the deposit
- The levels of stress involved
- The nature of the stress (tensile, compression, or shear)
- The operating temperature
- Other significant environmental conditions

Impact Resistance

Impact may be classified as light, medium, or heavy, depending upon the result of the impact energy.

An example of a heavy impact application is a hardfaced mill hammer. In light impact, kinetic energy is absorbed elastically. It is absorbed both elastically and plastically in medium impact. In heavy impact, the surface of even the strongest materials must either deform or fracture.