Use shot peening to toughen welds

Peening weld surfaces with steel shot induces compressive stresses that raise resistance to fatigue and corrosion.

By Tom Floyd

Shot peening improves property performance of welds and weldments by cancelling residual tensile stresses that develop in surfaces as welds cool and replacing them with compressive stresses. Compressive stresses raise resistance to fatigue, stress corrosion, and intergranular corrosion.

A cold-working process, shot peening bombards a metal workpiece with spherical pellets, commonly steel shot. Each impact stretches and densifies surface layers. Because subsurface material remains unstretched, it exerts an opposing force, trying to restore the surface to its original area. This force, compressive stress, preloads the metal surface against tensile loading stresses.

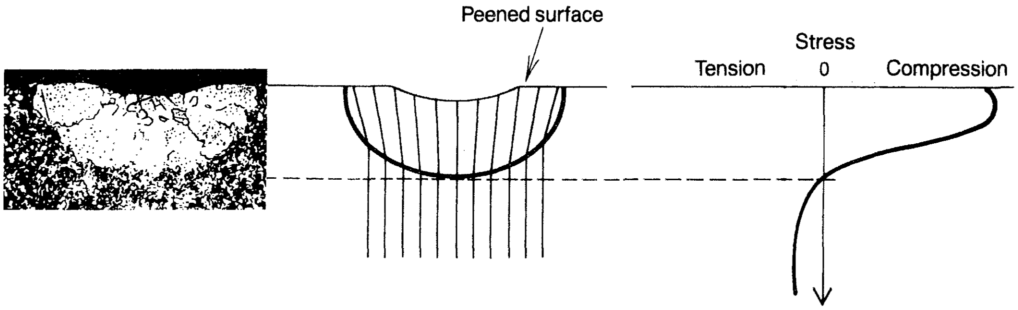
Testing shot-peened parts, researchers have demonstrated that peening raises fatigue resistance of fillet welds in carbon steel and butt welds in constructional alloy steel by 20 to 40 percent, and can double fatigue resistance of butt welds in aluminum plate and 18-percent Ni maraging steel. Researchers at Rockwell International (Atomic Division) found that shot peening prevents stress corrosion cracking of weldments in austenitic stainless steel.

Fatigue resistance improves because, when service imposes tensile stresses in a part, the built-in compressive stresses counteract them. This action keeps surface stresses in compression, allowing the part to withstand fatigue cycling for long periods.

Built-in compressive stresses raise resistance to stress corrosion by counteracting tensile stresses. Stress corrosion occurs when tensile stresses break up oxide layers that normally protect surfaces of chromium-containing alloys. Though bare metal re-oxidizes to form fresh oxide coatings, recurring cycles of tensile stresses continually rupture these layers.

As for intergranular corrosion, characteristic of stainlesses sensitized at weld temperatures, peening before welding helps to prevent it by breaking up surface grains. This action provides a multitude of nucleation sites for chromium carbides that would otherwise grow preferentially in grain boundaries, leaving chromium-depleted zones sensitive to corrosion.

PEENING DEVELOPS COMPRESSIVE STRESSES



Controls for peening

Operators consider expected service conditions when determining how deep compressive stresses should run beneath surfaces. Shallow peening, to 0.008 inch, suffices to counteract tensile stresses built up by simple bending and to forestall stress corrosion cracking. To combat tensile stresses imposed by complex bends and torsion, and to handle fretting fatigue, peeners recommend compressive depths to 0.015 inch.

To adjust depth of compression, operators adjust the energy at which pellets strike work surfaces. They measure kinetic energy on the Almen Intensity Scale, running tests with Almen strips, of cold-rolled SAE 1070 spring steel hardened and tempered to Rc 44 to 50. Measuring 3/4 by 3 inches, Almen strips come in three thicknesses: 0.031 inch (N strips, for thin work), 0.051 inch (A strips, for most jobs), and 0.094 inch (C strips, for heavy parts).

To run an Almen test, the operator clamps the strip to a jig, called an Almen block, then tightens four screws at corners to hold the strip flat. He positions the jig on the part, such that the test strip lies along the section of interest, say the surface of a butt weld. Then the operator starts a peening run, stopping the action periodically to inspect the strip.

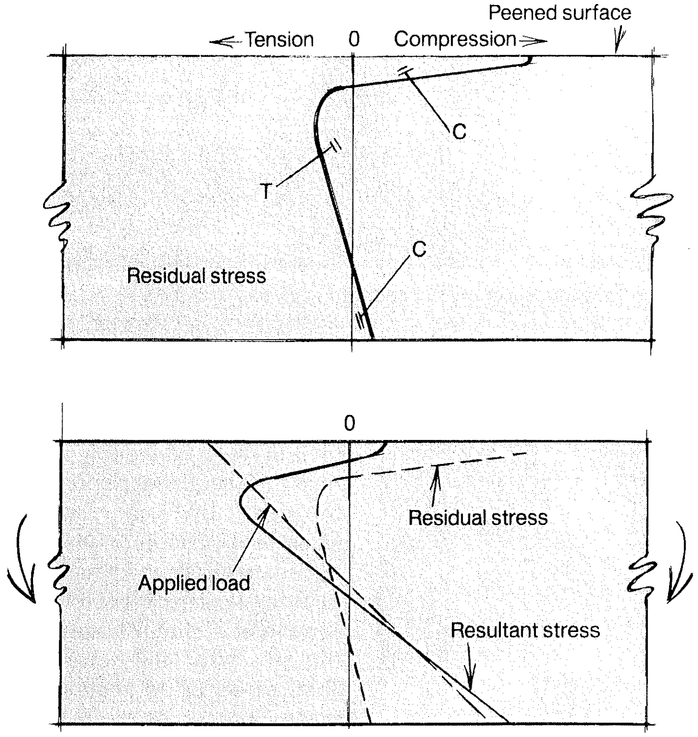
As peening proceeds, compressive stresses build up on the exposed side of the Almen strip, bowing it to a maximum curvature, called saturation. Curvature is measured with an Almen Gage, a dial gage scaled in mils. The operator records the corresponding arc height—an intensity of 10A means that an A strip is saturated with an arc height of 0.010 inch.

Almen intensities relate to compression depth, which varies with material and hardness. As the graph shows, an Almen intensity of 6C (0.006 inch on a C strip) corresponds to compression depths of 0.012 inch for steel at Rc 52, 0.015 inch for titanium-6Al-4V, and 0.022 inch for steel at Rc 31.

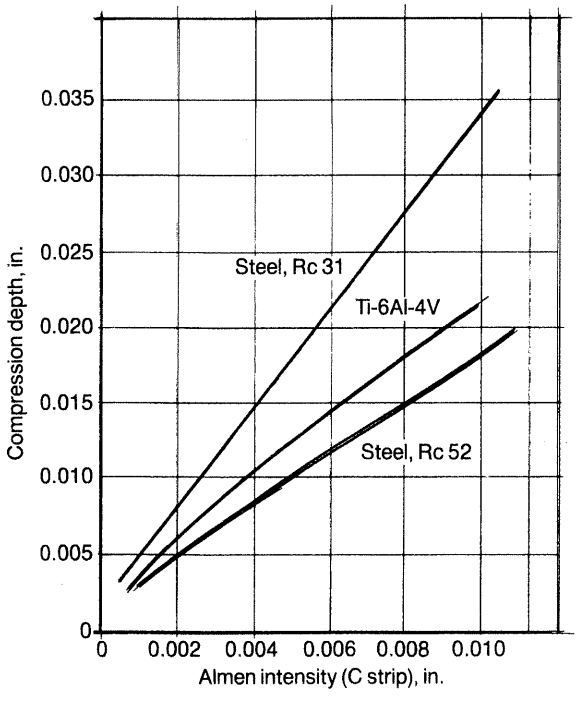
Peen all surfaces

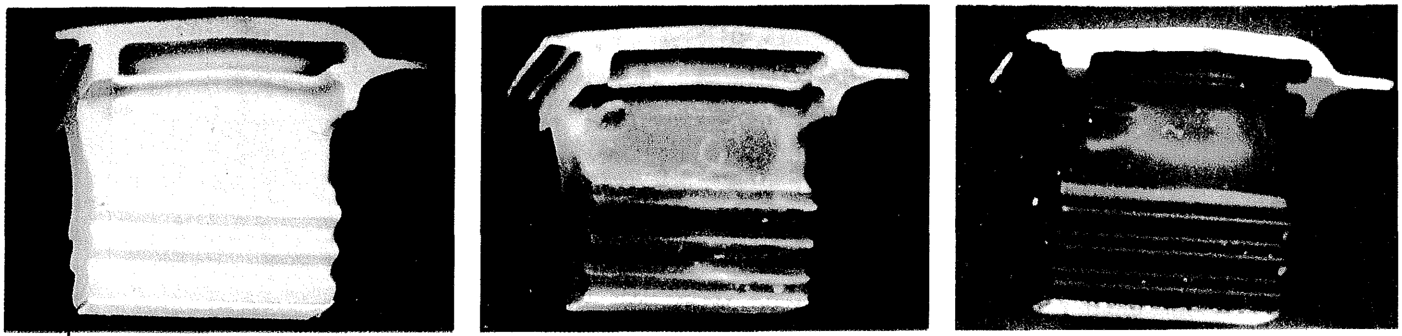
To raise fatigue resistance effec-

LOADS ALTER STRESS DISTRIBUTION

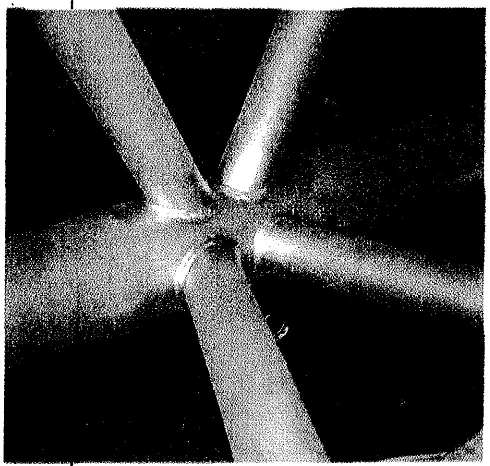


PEENING INTENSITY PREDICTS COMPRESSION DEPTH





To perform Peenscan inspection, the operator coats the part with fluorescent dye, which glows under black light (left). Peening for 15 seconds (center) removes some of the coating, such that the part continues to glow hazily. Glowing stops after 1 minute of peening (right) to demonstrate 100-percent coverage.



Operators shot-peen crane-boom welds to help them resist fatigue in service. Booms, of ASTM A618 steel (70,000 lb/in.^{2} tensile), go to draglines.

tively, peening must cover weld joints, including HAZs, completely—every square inch should be dimpled overall. Inspectors conventionally determine 100-percent coverage by examining surfaces thoroughly with a magnifying lens, ×10 power. Some customers call for

To raise fatigue resistance effectively, peening must cover part surfaces, determined by ×10 lens or black-light inspection of fluorescent-coated parts.

125-percent coverage, even 200-percent coverage, to make sure that they will get 100-percent coverage. The extra peening adds no benefits, but costs more.

With use, shot shatters, breaking up into sharp-edged fragments that nick surfaces. Since peening aims at building uniform compressive stress into surfaces without abrading material or introducing stress raisers, peening cannot tolerate broken pieces of shot. We start all peening jobs with 100-percent round shot, screened to remove broken pieces and sized to uniform diameters. In modern peening machines, classifiers screen out broken pieces continuously throughout peening runs.

Peening today

Late in the last decade, Peenamatic Division, Metal Improvement Company, adapted microprocessors to run shot peening production equipment. Microprocessors program machines, changing settings to peen parts of different materials, shapes, and sizes. They set, automatically, all parameters, including shot-impingement angle, Almen intensity, air pressure, and motion of the shot streams. The computer stores settings for repeat runs. It also monitors parameters during peening, and will shut the run down if a parameter, such as air pressure, strays out of the preset range.

Microprocessor-based systems adapt to statistical process control, which will become simpler when computer-monitored parameters replace Almen strips, a move planned before the year 2000. Computers will also predict shot degradation as a function of Almen intensity, type of shot, and target hardness.

Inspection has improved appreciably with the development of the Peenscan method, which takes the place of tedious examination by magnifying lens. Peenscan inspectors use black-light projectors to determine coverage. They start by coating the part with an alcohol-based fluorescent liquid, which dries rapidly leaving a thin film of fluorescent material. During runs, peening gradually removes the film, causing the glow to fade out, as viewed under black light. Complete disappearance of the glow indicates 100-percent coverage. Recognized by military specifications (MIL-S-13165B: *Shot Peening of Metal Parts*), Peenscanning eliminates the need for 200-percent coverage in order to be assured of complete peening.

Ceramic shot, another new development, gets the call when ferrous contamination might be a drawback, as when peening stainless steels. Harder than carburized steel, ceramic shot produces higher Almen intensities and fractures less than steel shot. Zirconia-silica shot will probably replace steel shot within 10 years.

Peening shops have devised innovative ways to peen out-of-the-way areas and corners of parts. They use flexible lances to deliver shot around corners, and employ internal shot deflectors to shot-peen insides of welded pipe. ■

Tom Floyd is manager of metallurgy, Cleveland Division, Metal Improvement Company, subsidiary of Curtiss Wright Corporation, 18683 South Miles Road, Cleveland, Ohio 44128; (216) 662-8408.