95005

Process Controls the Key to Reliability of Shot Peening

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Shot peening was recognized over a half century ago as a very economical way to extend the service life of automotive engine valve springs. Today "controlled shot peening" has developed into an advanced process regularly specified to prevent or to delay metal fatigue cracking and stress corrosion cracking (SCC) in the automotive, aerospace, chemical, petroleum, power generation and other industries. Peen forming, a related process, is also widely used to shape the complex aerodynamic contour of aircraft wing skins. More recently, "peen texturing" has found a niche in providing aesthetically pleasing finishes on decorative and architectural metals. Shot peening is not "shot or grit blasting" which are processes used to remove deposits or mill scale from surfaces. The applications for shot peening are much more demanding and require a process that is predictable, uniform and repeatable. While controlled shot peening is considered a mature process, it continues to evolve and gain ever increasing acceptance.

What is Shot Peening?

In shot peening, spherical media (termed "shot") made from cast or wrought steel and stainless steel, as well as from ceramic or glass beads, are propelled against a workpiece with sufficient energy and for a sufficient time to cover the surface with overlapping cold worked dimples. This dimpling causes plastic strain and stretching of the surface fibers. As this is resisted by the unaffected sub-surface material, a state of residual compressive stress is induced in the surface and near surface layers of the workpiece (Fig. 1). The compressive stresses eliminate any detrimental residual tensile stresses from grinding, heat treating, welding, plating or hard coating. In addition, when the shot peened component is subjected to an external load such as bending, the compressive stress also acts to reduce the level of applied tensile stresses at and near the surface where almost all fatigue and stress corrosion cracking failures initiate (Fig. 2). Because the peak residual compressive stress occurs near the surface, shot peening is most effective in the presence of an applied stress gradient, such as that due to bending or torsion or to local stress raisers such as notches, fillet radii, section changes, welds, or surface defects.

What Does Shot Penning Accomplish?

The benefits of shot peening have been documented in thousands of laboratory experiments and full scale component tests, and confirmed by years of service experience (Figs. 3 and 4). While strain hardening plays a role, the major benefit derived from shot peening is the result of the residual compressive stress. Progressive fracture mechanisms such as metal fatigue and stress corrosion will not initiate or propagate in a compressive stress field, or if the algebraic sum of applied tensile stress and residual compressive stress is below some crack propagation tensile stress threshold value. Because of this, of paramount importance to the design engineer are the peak magnitude, total depth and stress/depth profile of the residual compressive stress. For most structural alloys, these values can be quite accurately predicted from the workpiece mechanical properties and from the major shot peening parameters. Computer aided prediction of the shot peening residual stress is now available. Unfortunately, there is at present no reliable non-destructive examination (NDE) method capable of verifying residual stress/depth profiles. Non-destructive surface measurements by X-Ray Diffraction, although currently being used, are not considered by most to be a reliable criteria of peening uniformity or quality. The absence of a practical NDE method for verifying the effectiveness of a shot peening operation increases the need for reliable process controls.

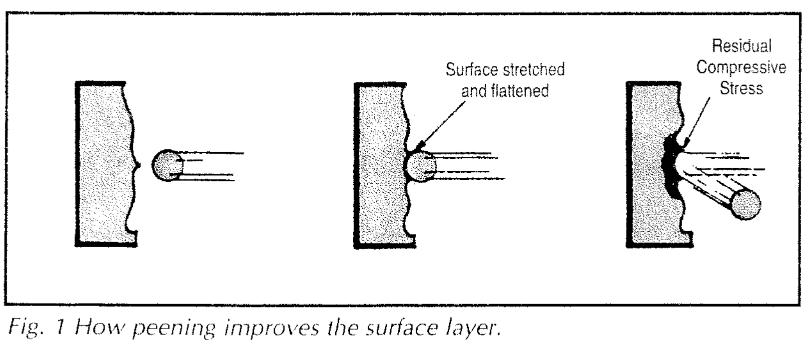

Fig. 1 How peening improves the surface layer.

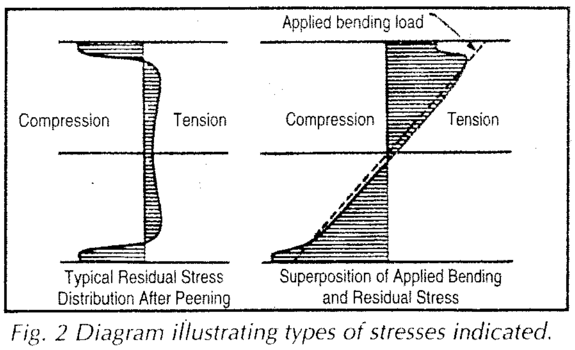

Fig. 2 Diagram illustrating types of stresses indicated.

What Process Variables are Controlled?

In order to effectively ensure process repeatability and uniformity, the following parameters must be controlled:

Intensity - The peening intensity is an indication of the kinetic energy transfer from the shot stream to the workpiece. It is a function of the shot size, shape, material, hardness, velocity and impingement angle. It is determined using the Almen method described in SAE J442 and J443. In the method, an unpeened strip of SAE 1070 spring steel (called an Almen strip) is fastened to a steel block (strip holder) and exposed to the shot stream for a specific time. When removed from the block the strip assumes a curvature, convex on the peened surface, due to the residual compressive stress introduced by the peening. The amount of curvature or arc height is measured using a standard Almen gage. There are three standard Almen strips: A, 0.051 in. thick; C, 0.094 in. thick; and N, 0.031 in. thick. Strip A is used for testing intensities that produce arc heights of 0.006 to 0.024 inch. The N strip is used for lesser intensities and the C strip for greater intensities. The standard designation for intensity includes the arc height (x 10 -3 in.) and the test strip used. For example, an intensity of 10 A signifies an arc height of 0.010 in. on an A strip.

When measured at or above saturation of the Almen strip, the arc height is called the intensity. It is a measure of the effectiveness of the peening operation on a specific part. Saturation is defined as the first point on a curve of arc height versus exposure time where a doubling of exposure time results in an increase in arc height of no more than 10%. The Almen test is the primary standard of quality control in peening. In practice, several strip holders are mounted on a simulated part, called an Almen fixture, at the critical locations selected for peening. This Almen fixture is then placed in the peening cabinet and processed using the same parameters as those specified for production parts. Intensity is established by verifying the saturation point (see Fig. 5).

Media - Shot should be spherical with no angular or broken particles because angles and sharp edges can be damaging to the part surface. Shot must also be uniform in size. Shot must be small enough to impart sufficient cold work to the smallest radius on the part being peened, and large enough to produce the required intensity. Shot classifiers are used to continuously segregate the peening media by both size and shape, removing non uniform, undersize and other unacceptable particles.

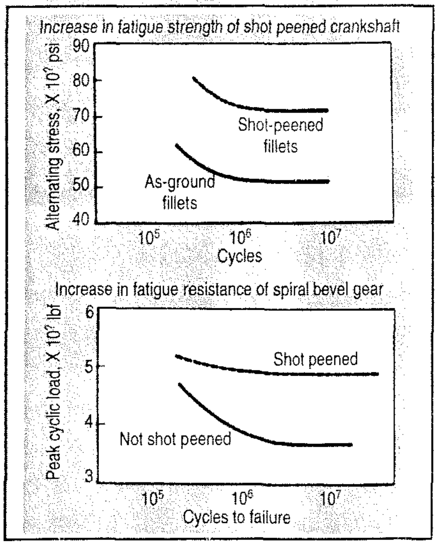

Fig. 3 Examples of effects of peening on fatigue of parts.

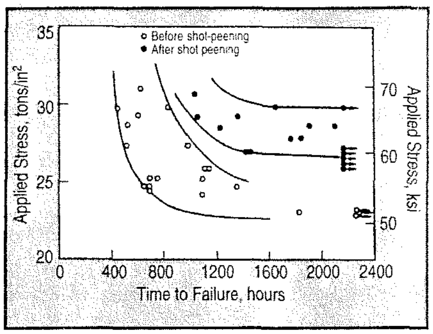

Fig. 4 Results of stress corrosion tests on peened and unpeened specimens (5054 aluminum alloy).

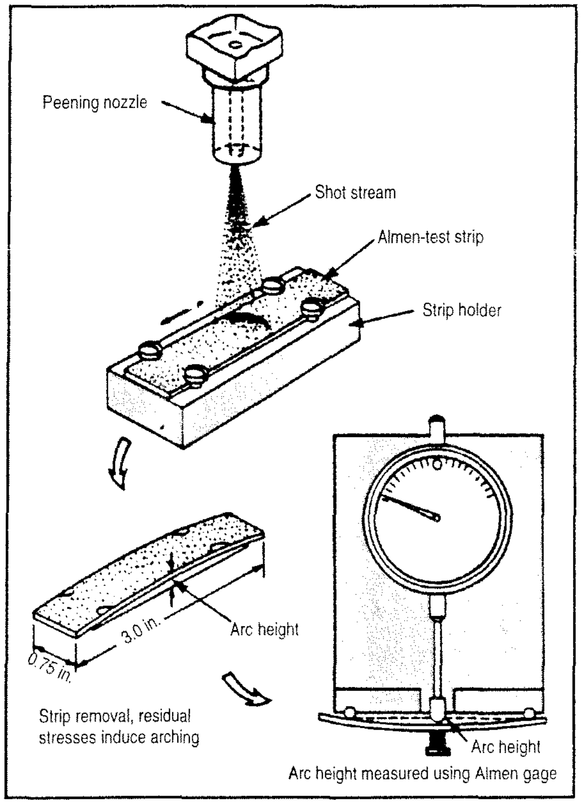

Fig. 5 Almen strip system for determining peening intensity.

Coverage - Most applications require that peening completely obliterate the original surface finish of the part. The traditional method of verifying 100% coverage is to use low power magnification (10x). Accuracy depends on the skill and experience of the person doing the testing. An alternative method, using an approved liquid fluorescent dye tracer, is described in MIL-S-13165 in accord with the following procedure. The workpiece is coated with the tracer which dries to an elastic film. After peening, the part is examined under ultra-violet light, and the amount of tracer removed by peening provides a measure of the degree of surface coverage. Coverage greater than 100% can be obtained by peening for times which are multiples of the time required for 100% coverage.

Computer Enhanced Shot Peening

In recent years, control of the shot peening process has taken another step forward with the introduction of computer monitored shot peening systems designed to check on, control and document critical machine settings such as air pressure and shot flow at each nozzle, workpiece rotation or translation rate, nozzle reciprocation rate, nozzle/workpiece distance, run time for each nozzle, and total cycle time. At least once every second, the computer compares each processing parameter to preset maximum and minimum limits. When a deviation is noted, the peening operation is shut down automatically and the fault is displayed. After corrective action is taken, the process is restarted at the point where it left off. Data collected by the peening machine computer during production are forwarded to a master computer, where it becomes part of the job's permanent record. Fig. 6 shows a flow diagram representing software control of the peening process and includes a sketch of a typical computer controlled machine for high production.

Requirements

Despite the emphasis on controls, both traditional and computer enhanced, some input data from the peening specialists are required. It is the responsibility of the specialist to select the type, hardness and size of shot. The specialist also should insure that the drawing, or sketch, of a part requiring shot peening includes the following: areas to be peened; areas to be masked; optional peening areas; areas where peening fades out, if any; shot size, hardness and material; locations

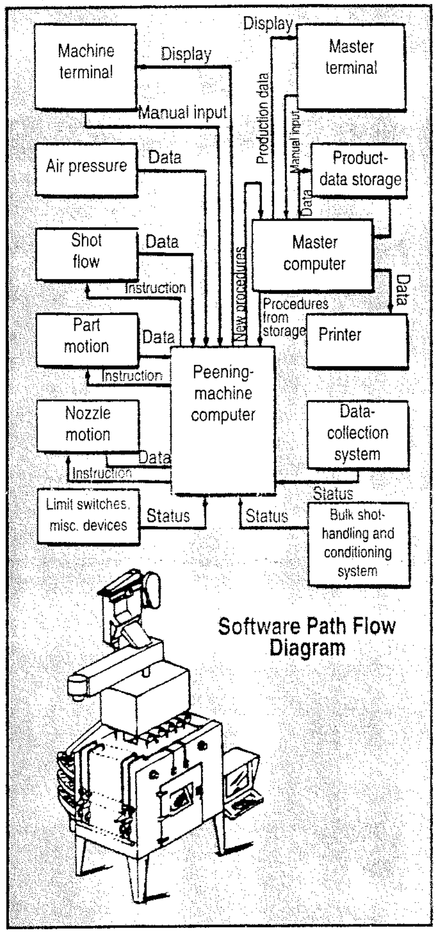

Fig. 6 Computer controlled shot peening machine and flow diagram representing control of the process.

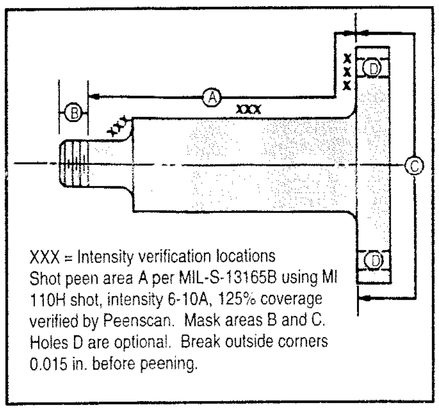

Fig. 7 Typical shot peening call-out.

for intensity verification and the intensity range at each location; coverage requirements for all areas to be peened, including the method to be used for verifying coverage, and applicable shot peening specification.

The sketch also should show major dimensions and any critical measurements, such as fillet radii and diameters of holes that are to be peened (see Fig. 7). IH

How to tell if you might be a "high tech redneck"
(source unknown)

If your e-mail address ends in ".over.yonder.com"

If you connect to the World Wide Web via a "Down Home Page"

If the bumper sticker on your truck says "My other computer is a laptop"

If your laptop has a sticker that says "Protected by Smith and Wesson"

If you've ever doubled the value of your truck by installing a cellular phone.

If your baseball cap read "DEC" instead of "CAT"

If your computer is worth more than all your cars combined

If your wife said "either she or the computer had to go", and you still don't miss her

If you've ever used a CD-ROM as a coaster to set your beer on

If you ever refer to your computer as "Ole Bessy"

If your screen saver is a bitmap image of your favorite truck, tractor, or farm animal

If you start all your e-mails with the words "Howdy y'all"

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