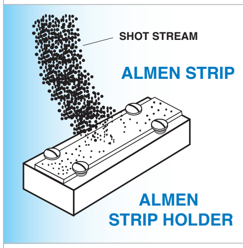


Key Terms in Intensity Control

for the New Shot Peening Technician

Intensity control is essential for process reproducibility and repeatability and it's an area where many new shot peening technicians could use a helping hand.

In an effort to help, we've supplied definitions for the key terms in the intensity control process.

almen strip. Almen strips are test coupons made of SAE spring steel that measure the energy of the shot stream, or the "intensity." The strip is fixed to a holder and is exposed to the shot stream. The residual compressive stress imparted into the strip from peening will cause the strip to arc toward the peened side when released from the holder. The amount of "arc height" is a function of the intensity and is quantifiable and repeatable. The strip's arc height is measured on an Almen gage.

Almen strips are categorized by thickness into three groups: "N", "A", and "C". The strips can be further classified by flatness (prebow) and hardness.

Thickness
"N" strip thickness = 0.031" (0.79 mm)
"A" strip thickness = 0.051" (1.29 mm)
"C" strip thickness = 0.094" (2.39 mm)

The thickness determines a strip's ability to arc during peening so each strip has an appropriate intensity range, as expressed by the arc height measurement from an Almen gage.

The "A" strip is considered the standard strip and is used when the required intensity range is .004'' - .024''. When an intensity lower than .004'' is required, the thinner "N" strip should be used. The "C" strip is used to achieve an intensity above .024''.

The length and width are the same for all three strips: 3" x .75" (76.2 mm x 19.05 mm).

Flatness. See **prebow**.

Hardness
Hardness affects the strip's performance: As hardness increases, the arc height decreases. "A" and "C" strips have a hardness range of HRc 44-50. "N" strips have a hardness range of HRa 72.5-76.0. In more critical applications like aerospace, the part's designer will specify an Almen strip with a smaller hardness range.

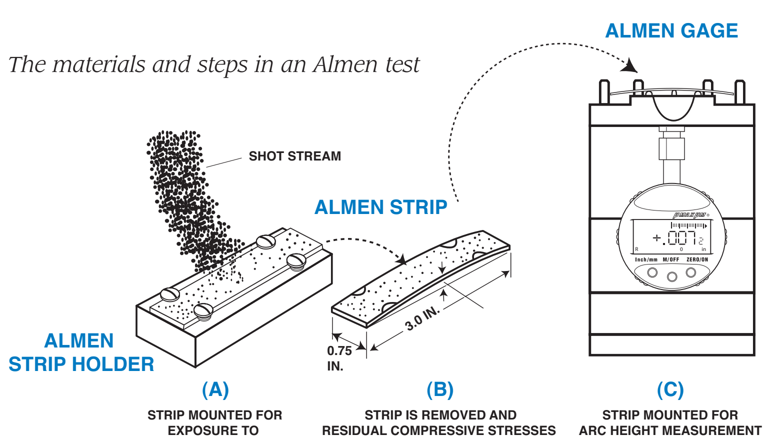
almen gage. An Almen gage measures the height of the arc of a peened Almen strip. The "arc height" is the quantitative representation of the applied force of the shot stream or the "intensity" of the shot stream. The energy of the shot stream directly influences the amount of compressive stress imparted into the surface of a component.

Almen gages have a digital readout with a .0001'' (.001 mm) display and .00005" (0.00127 mm) resolution. The high degree of resolution improves accuracy and ensures repeatability and reproducibility in the shot peening process. See Figure 1.

almen strip holder. Almen strips are mounted on an Almen strip holder for exposure to the shot stream. Almen holders are mounted on a test part or custom fixture and placed in locations where verification of the energy of the shot stream (intensity) is crucial. See Figure 1.

almen test. An Almen test is a crucial part of a controlled shot peening process because it

Figure 1. The materials and steps in an Almen test



verifies intensity. Intensity is the energy of the shot stream and it directly influences the amount of compressive stress imparted into the surface of a component.

Almen strips, gages and holders are the industry-standard tools for an Almen test—a procedure to measure the arc height of a shot-peened Almen strip. The arc heights from Almen tests are used to plot a Saturation Curve. Data from a saturation curve verifies the appropriate intensity reading for the process. **See saturation curve**.

An Almen test ensures that the shot peening machine is set up and running according to the approved parameters so that damage to valuable parts is prevented. Almen tests are repeated during long production runs to verify that the processing parameters haven't changed.

arc height. Arc height is the degree of curvature of a peened Almen strip as measured on an Almen gage and is expressed in inches or millimeters. It is the quantitative representation of the applied force of the shot stream.

almen intensity. The Almen intensity is a designation that specifies the arc height (as measured on an Almen gage) and the Almen strip type. For example, the proper designation for a 0.012'' (0.30 mm) arc height using the A strip is 0.012A (0.30A). This designation is often simplified to "12A."

coverage. *Coverage (noun): The extent to which something is covered.*

Coverage is the measure of the original surface area that has been covered by shot peening dents. It's one of the key parameters of the shot peening process and is controlled by equipment cycle time.

Coverage is specified by a percentage. If the goal is "100% coverage," the length of machine cycle time to achieve 100% coverage will depend on the hardness of the material to be peened.

The machine cycle time to achieve 100% coverage is determined through visual inspection and can be corroborated with coverage check tools. Once established, the shot peening technician uses this time as a base to achieve levels of over-coverage (for example: 150%, 200%, 300%).

The concepts of coverage and saturation, and the timing necessary to achieve both, are confusing to new and experienced shot peening technicians. It takes longer to achieve 100% coverage than it takes to achieve "saturation," the required intensity reading of a shot peening procedure derived from a saturation curve. The "peening time" in the saturation curve graph is NOT the machine cycle time needed to achieve 100% coverage on the Almen strip. Also, the amount of machine cycle time necessary to achieve 100% coverage on the component will be different than for an Almen strip due to differences in material hardness. See **saturation curve**.

exposure time. Exposure time (also called "peening time") is the time variable when developing a saturation curve. Exposure time is not the appropriate length of time for the machine cycle; however, since it will take longer in most cases to achieve the desired amount of coverage on an Almen strip and the component. See Figure 2 and **saturation curve**.

intensity. Intensity is the measure of the energy of the shot stream. The energy of the shot stream directly influences the amount of compressive stress imparted into the surface of a component. Surface residual compressive stresses provide resistance to metal fatigue and some forms of stress corrosion. Intensity can be controlled by media size, media type, media impingement angle and shot stream velocity.

Intensity is expressed as the arc height measurement of a peened Almen strip on an Almen gage. For example, a specification requests a .010 ±.002 A. An intensity of 0.010" is called for with an approved variance of 0.002" on a type "A" Almen strip. The acceptable range is from 0.008" to 0.012".

intensity verification. See **saturation curve**.

metal fatigue. Metal fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loadings—loads that are applied over and over again. If the loads are above a certain threshold, microscopic cracks will begin to form at the surface. Eventually a crack will reach a critical size and the structure will fracture.

Shot peening creates residual compressive stresses that confer resistance to metal fatigue. See Figure 3 on page 16.

plasticity. Plasticity is the deformation of a material undergoing non-reversible changes of shape in response to applied forces. In shot peening, shot impacts the metal and makes dents. The peened metal then displays plasticity because permanent changes have occurred within the material's surface.

prebow. Pre-bow, or the variation from "perfect" flatness, in the unpeened Almen strip acts like a latent bias in the arc height measuring system. A strip that has a pre-bow of .001 inch will have a .001 inch higher arc height than a strip with zero pre-bow. If the initial pre-bow value is negative, than the resulting arc height will be diminished by the same amount. A compensation scheme may be used to negate some of these effects by taking a net reading of the strip arc height.

Almen strips are classified in grades of varying prebow tolerances to meet a wide range of applications, from automotive to aerospace.

residual compressive stress. Residual stresses are stresses that remain after the original cause of the stress has been removed. Shot peening creates residual compressive stress, a beneficial stress that provides resistance to metal fatigue and some forms of stress corrosion. See **stress**.

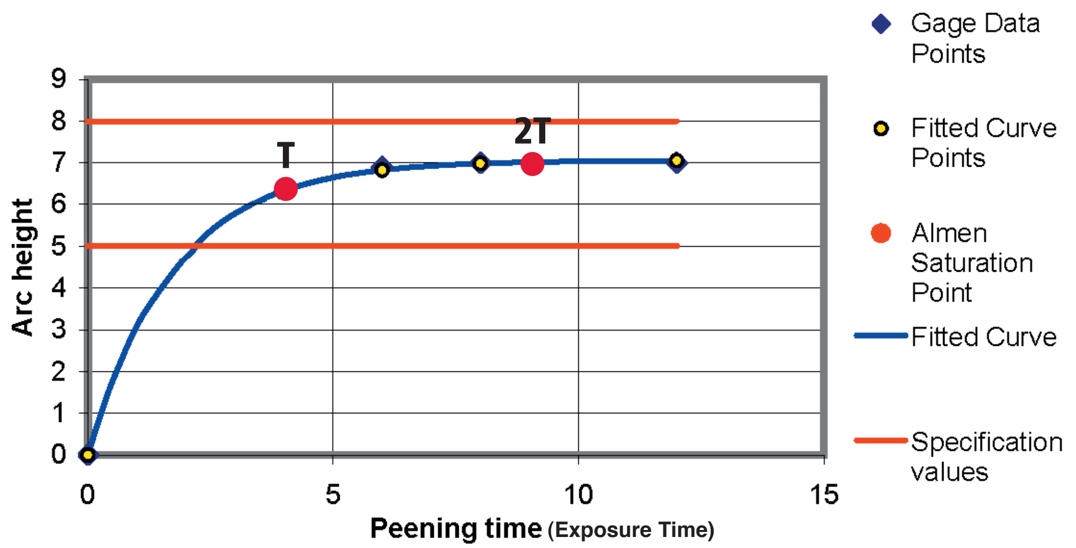


Figure 2. Saturation occurs when doubling of the peening time (2T) from T results in less than a 10% increase in arc height. The saturation curve was plotted with a computerized curve solver program.

saturation curve. *Saturation (noun): The state or process that occurs when no more of something can be absorbed, combined with, or added.*

A saturation curve is the graphical plotting of arc height versus exposure time to determine "intensity" (the velocity of the shot stream). It's the accepted method for verifying or establishing the requested intensity reading. The saturation curve is plotted with a minimum of four arc height readings that were taken during a peening session with fixed machine parameters. Saturation is defined as the earliest point (T) on the curve where doubling the peening time (2T) produces a 10% increase in arc height. This is called the 10% Rule. The arc height at "T" is then used as the intensity reading of the shot stream at a given time for a particular machine setup. If the arc height reading at "T" is not within the requested tolerance band, then machine adjustments must be made and a new saturation curve generated. See Figure 2.

saturation curve solver program. Plotting arc heights for a saturation curve is time-consuming and often inaccurate. Computerized curve solver programs are available that simplify the procedure.

specification. A specification is an explicit set of requirements to be satisfied by a material, product, or service.

The products and procedures of the shot peening process are regulated by public specifications like those issued by the Society of Automotive Engineers (SAE), a customer-supplied specification or an in-house spec. The shot peening requirements in a specification will typically have these components: References to an applicable industry specification (for example: SAE J442), the area to be peened, the media and the intensity.

stress. When a force is applied to an object, the object is said to be experiencing stress. Stress is effectively a measure of an object's response to a force. Stress can either be positive or negative depending upon the nature of the force. If a region of a component is stretched, then the stress is generally positive, or tensile. If the region is squeezed then the stress is negative, or compressive.

Tensile stress is usually considered bad, a compressive stress is usually considered beneficial. Imagine a small crack that has formed in a surface (Figure 3). If the stress around the crack is tensile, the crack is pulled apart by the stress and becomes deeper.

On the other hand, if the stress is compressive, then the crack is pushed together and grows no farther. Shot peening puts residual compressive stress into the surface of a metal to inhibit or slow the growth of cracks and thus improve the fatigue life and wear resistance of critical components.

tensile stress. Tensile stress (or tension) is the stress state leading to expansion; that is, the length of a material tends to increase in the tensile direction. Tensile stress is the opposite of compressive stress as compressive stress is the stress on materials that leads to a smaller volume. See Figure 3.

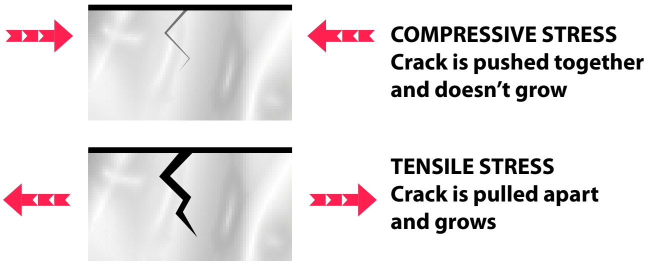


Figure 3. Compressive and Tensile Stress Comparison
Based on a drawing by Darren Huges, Institut Laue-Langevin in Grenoble, France