To specify that a component is to be shot peened, without saying how much in measurable quantities, is equivilent to saying "heat treat", without mentioning time or temperature. The method for measuring, and thereby controlling shot peening, uses the Almen test strip and the Almen gage.

Peening intensity is a measure of the energy of the shot stream which may be likened to the temperature in a heat treating operation.

Peening intensity is a measure of the energy of the shot stream which may be likened to the temperature in a heat treating operation. The temperature of the metal being treated is usually determined by measuring the temperature of the furnace in the vicinity of the work and exposing the work to that temperature for a sufficient time to saturate the metal. Unless both temperature and time are correctly specified, and unless the specification is followed, the heat treating process cannot be successful.

The control of a peening machine operation is primarily the control of the properties of a stream of shot and its relation to the work being peened.

The basic measurement of these properties is as follows:

1. A flat strip of steel is clamped to a solid block
2. exposed to a stream of shot and
3. upon removal from the block it will curve.

The curvature will be convex on the peened side. The extent of curvature on this standard sample serves as a measurement of the blast stream energy.

The degree of curvature depends upon the

1. properties of the shot

a. Size

b. Shape

c. Density

d. Hardness

2. nature of the exposure to the shot stream

a. Shot flow rate

b. angle of impact

c. exposure time

d. velocity

3. properties of the test strip

a. Physical dimensions (thickness, flatness, size)

b. Mechanical properties

The Almen test strip (Fig. 1) is fixed to a hard, flat metal block and peened on one side. When the strip is removed from the block, the residual compressive stresses induced by the peening causes convex curvature of the strip on the peened side. The curvature is measured in terms of arc height over a standard chord by a special dial indicator.

The holding fixture for the test strip is also shown in Fig. 1. The holder is securely fixed to a dummy part at an attitude that represents the area of coverage desired. For complex shapes, multiple holders may be required.

By exposing several Almen strips to the shot stream at increasing time intervals and graphically presenting the data (Fig. 2) the shot stream energy may be determined.

The amount of curvature, or arc height of the strip at the knee of the curve is called intensity. The peening intensity is the overall effect of the magnitude of the induced stress, the depth of the stressed layer, and the uniformity of the stress, in magnitude and depth, over the surface of the strip (coverage). Since the peening intensity measurement is made on a steel strip of standard dimensions and standard physical properties, the magnitude and depth of the induced stress are those of the test strip and not of the metal being peened.

Almen strips are available in three thicknesses to provide gaging low, medium and high intensity shot stream energies. The "A" strip should be used for specified intensities of .006A to 0.24A. For lesser intensities the "N" strip should be used, and for greater intensities the "C" strip should be used.

For critical applications, premium grade strips with certification of specification compliance should be used. These are manufactured to meet the U.S. military specifications MIL-S-13165 and are also certified to meet SAE J442. The certificate of compliance assures conformity to flatness, thickness and hardness by 100% inspection. The manufacturers certification of metallurgical composition is also included to provide traceability.

If non-premium grade strips are used then the operator must measure the strip for flatness and thickness prior to peening. (Note: operator should inquire if strip hardness should be measured, perhaps as part of incoming inspection).

Almen strips are fabricated from SAE 1070 cold rolled spring steel. The finish is blue temper (or brighter), uniformly hardened. They are heat set between flat plates under pressure for a minimum of 2 hours at 800 degrees F (+/- 25 degrees F) to relieve internal stresses.

The SAE J442 range for hardness is Rockwell C 44 to 50.

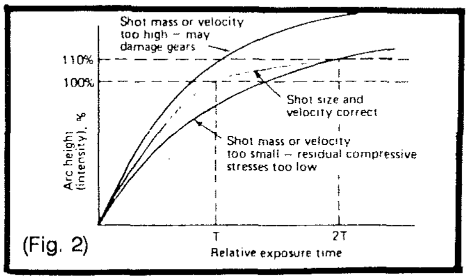
The SAE J442 limit on flatness is A: +/- 0.0015 N: +/- 0.001 C: +/- 0.001

Proprietary specifications may require tighter tolerances than these.

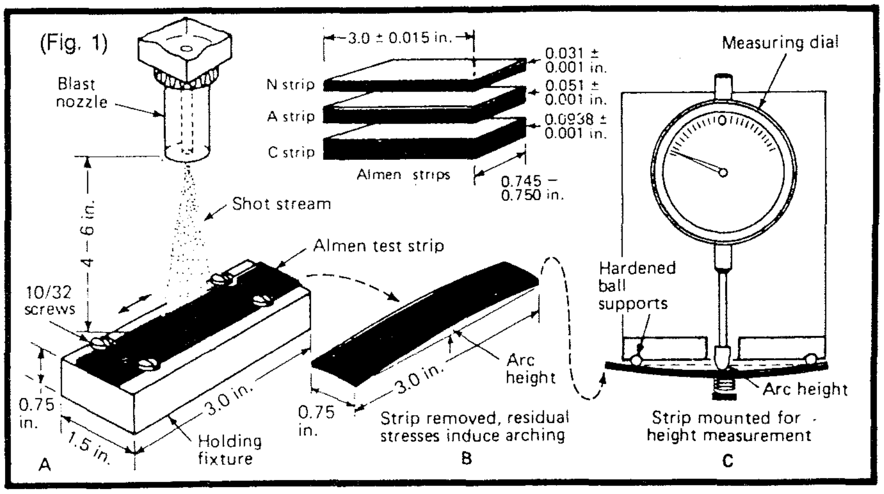
The choice of SAE 1070 spring steel was predicated upon its peening stress saturation feature. When exposed to a stream of shot the metal will endure impacts that result in compressive stresses and curvature until the surface is uniformly indented. Thereafter additional impacts do not increase the stress and no additional curvature results. In this respect the Almen strip acts as a thermometer exposed for a sufficient time to achieve (saturation) a true reading.

From this we can reason that use of the Almen strip requires assurance that it is "exposed" long enough to saturate. This can only be done by multiple trials with each trial being of longer duration until no additional curvature results. A graph is made from these trials and a curve is drawn similar to Figure 2. For convenience, saturation is defined as that point where the curve exhibits a knee. To verify this point, the exposure time is then doubled. If the curvature does not increase by more than 10%, then saturation has been achieved.

Prolonged exposure of the Almen strip to the shot stream may lead to surface erosion and reduced curvature. For this reason confirmation test strips (during production) should always be performed at exposure times used in the initial set-up Almen strip development. Peening a test strip for periods substantially longer (or shorter) than described above may lead to erroneous conclusions.



(Fig. 2)



Continued on Page 6...

Almen strip intensity determination.

The following procedure is a general guideline:

1. Attach the Almen test strip to the test holder. Be sure it is tight and flat against the holder.

2. Expose the test strip to the shot stream and record the exposure time (or its equivalent).

3. Remove the test strip and measure its curvature on the Almen gage. Be sure to check the zero point of the gage before each use.

4. Repeat the process for different exposure times in order to develop a curve as shown in Figure 2.

5. Determine the shot stream energy, or intensity, from the curve.

Production set-up procedure

Most peening processes specify intensity and shot size. In order to achieve the desired residual stress levels that are uniformly distributed over the entire surface, the coverage must also be specified. NOTE: COVERAGE IS NOT DETERMINED BY THE ALMEN STRIP SATURATION CURVE.

Coverage is defined as the complete denting of the surface. Ideally, this would be done by full size shots traveling at maximum velocity with an impact angle of 90 degrees to the surface. Impacts by smaller shot at lower velocity and lower impact angles do not contribute to additional compressive stresses.

Coverage is determined by exposing the actual workpiece or a sample of the target material (not an Almen strip) to the shot stream of previously determined intensity. The workpiece is then examined visually and an estimate of coverage is made and recorded. Additional samples are exposed at longer intervals until 100% coverage of the surface is accomplished. The exposure time required for coverage is not to be inferred from the Almen strip exposure time since material softer than 44-50 Rockwell C will achieve coverage quickly and material harder than 44-50 Rockwell C will require longer exposure. This is due to the size of the dent the impinging shot can make on various hardness materials. (Even materials of RC hardness of 44-50 but different modules of elasticity may receive coverage at different rates.

There are two distinct processes involved here. One is intensity determination, using the Almen strip saturation curve. The other is coverage determination, using visual examination of actual workpiece material indentation.

Once the coverage exposure time is determined the machine exposure cycle time may be established. If the workpiece component specification does not specify coverage, then 100% is assumed and machine exposure cycle time will equal the coverage exposure time.

Do not arbitrarily use the Almen strip saturation time as a guide to setting the machine cycle time.

The following production procedure is a general guideline:

1. Securely fix the test holder in a manner that simulates the critical surface(s) of the part to be peened. In some cases more than one setup may be required. Generally, a non adjustable fixture is preferred.

2. Using an estimated machine setting (shot flow rate and velocity and shot type and size) perform the Almen strip saturation development and determine intensity.

3. If the intensity achieved is not within specification, then, machine settings affecting intensity must be changed (assuming shot size is fixed). If a higher intensity is required then higher velocity must be used. Conversely, if a lower intensity is required, a lower velocity must be used. Velocity may be changed by adjusting wheel speed or air pressure.

(Changes in nozzle size and type may also be used to obtain the desired velocity).

4. Insure that targeting is correct by peening and examining a sample workpiece. If complete and uniform coverage of the intended area is not achieved then adjust the targeting and/or machine cycle time and repeat step 2 and 3 above. Note the time required to achieve 100% coverage and set the machine cycle timer accordingly.

5. Any changes in targeting, flow rate or velocity will require repeating step 2, 3 and 4 above.

Confirmation

Unless otherwise specified, confirm both intensity and coverage every two (2) hours of operating time. At least two Almen strips should be used to confirm intensity. The first strip exposure should be at Almen strip saturation time and the second test strip exposure time should be 200% of the Almen strip saturation exposure time and examined for 10% increase. Do not use the standard machine workpiece cycle time for confirmation of intensity using Almen test strips. Use the Almen strip saturation time from step 3.

The coverage confirmation consists of inspecting a workpiece for proper coverage. The machine cycle time is then reduced to the level where coverage (from step 4) was found to be 50% complete (visual confirmation). A workpiece is then peened at this cycle time to confirm 50% coverage. (The choice of 50% is recommended because of the relative ease of estimating 50% coverage. Distinguishing, say, 80% is somewhat more difficult. Use of flourescent tracer as a coverage indicator should be confined to situations where the tracer removal rate has been definitely correlated to impact coverage.

If either intensity or coverage tests are not within specification then the processing must be halted to determine the cause. DO NOT CHANGE THE VELOCITY (INTENSITY) OR FLOW RATE OR EXPOSURE TIME (COVERAGE) WITHOUT DETERMINING THE TRUE CAUSE OF THE PROBLEM.

Most controlled shot peening machines have air pressure (velocity) and flow rate (coverage)monitors and alarms to show process variation. If these process parameters are within tolerance while intensity and coverage have changed, then it is very likely that the shot quality has changed. Addition of new shot, which may be harder or softer, may cause an intensity change. A malfunction in the shot seperator/classifier system that doesn't eliminate broken particles may result in lower intensities. Arbitrarily increasing air pressure to compensate for lower shot mass may appear to increase peening intensity. However, the workpiece surface may now receive surface damage due to the sharp, angular particle impacts. DO NOT CHANGE THE VELOCITY (INTENSITY) OR FLOW RATE OR EXPOSURE TIME (COVERAGE) WITHOUT DETERMINING THE TRUE CAUSE OF THE PROBLEM.

Do not change any of the machine settings unless you plan to run a new profile of intensity and coverage.

Consistent Peening Operation - Conclusion

Following the above peening process procedures and maintaining the process within specifications is only the beginning. Although it's beyond the scope of this article, statistical process control methods, or SPC, must be used to insure continued success. The technique of graphically presenting intensity data will provide evidence of correct targeting, intensity and coverage specification compliance. SPC can be used to demonstrate that the process is, indeed, "Controlled Shot Peening".

Recommended references:

"Controlled Shot Peening" The Shot Peener, Champaigne

Manual on Shot Peening SAE J808H

Mechanical Prestressing Report SAE SP181

MIL-S-13165 Shot Peening of Metals

MIL-S-851 Shot Peening of Metals

SAE J442 Shot Peening of Metals

SAE J443 Shot Peening of Metals

"Shot Peening" Wheelabrator Corporation (book)

"Shot Peening" ICSP I (book)

"Shot Peening" ICSP II (book)

"Shot Peening" ICSP III (book)

"Application Note Catalog" (list of articles) from The Shot Peener

Almen Strip Operator Training (video tape-15 minutes) from The Shot Peener