The Little Book on Shot Peening
Electronics Incorporated © 2001
Jack Champaigne 28 August 2001

1. Description of Peening

Shot peening is a special metal surface treatment intended to extend the fatigue life of most metals. The impact of small spherical media called shot creates a dent in the surface that is very beneficial in preventing formation of fatigue cracks. The area below each dent called the plastic zone, typically only .020 inch deep, is highly compressed and this action tends to keep cracks from opening in the surface. Valve springs, suspension springs, leaf springs, torsion bars, gears and connecting rods are all treated with shot peening to extend their service life. This book will explain the essential elements necessary to properly apply shot peening. The most important thing to remember is “We make dents”. They must be applied in the correct area of the part (location), they must be the right size and there must be enough to entirely cover the surface and it must be done with the proper size and hardness of shot.

We make dents.

2. Machines

Although peening and abrasive blast cleaning can be performed in a special room called a blast room most peening is conducted in a special cabinet designed to safely confine the media and provide proper aiming of the shot blast stream. The shot can be propelled by a spinning centrifugal wheel or by an airblast nozzle. Wheel peening is popular for very large quantity production, especially in the automotive sector. Airblast is used for smaller quantities of parts and when tight tolerances are required, especially in the aerospace sector.

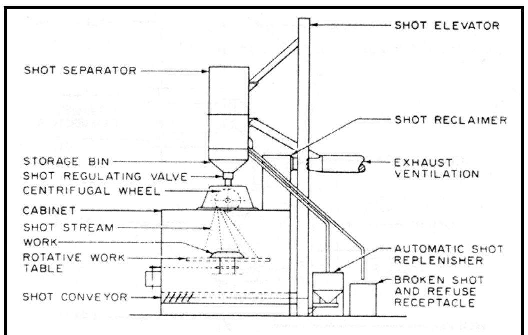

Figure 1. Wheel blast machine

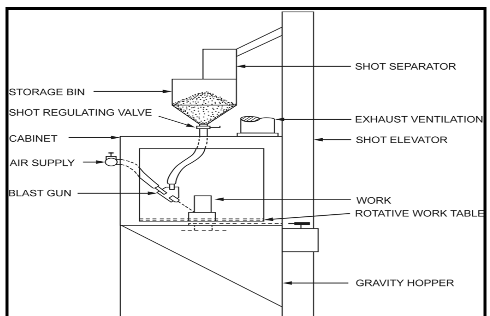

Figure 2. Gravity-nozzle machine

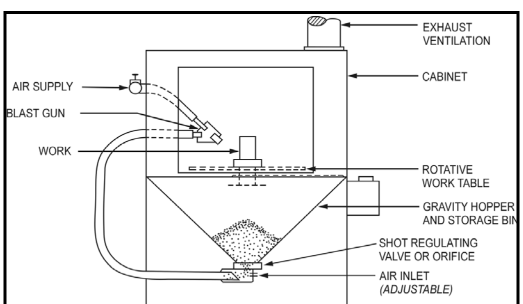

Figure 3. Suction-induction nozzle machine

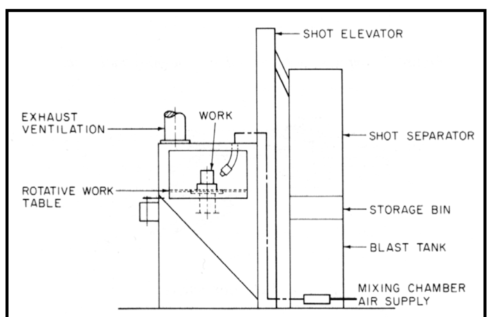

Figure 4. Direct pressure machine

Other equipment associated with the machine is necessary to recycle the shot and provide for dust collection and disposal for the broken shot. The shot must be collected from the bottom of the machine and lifted, either by pneumatic conveyor or bucket elevator to the shot classifier system. The pneumatic system will have a cyclone separator that will swirl the air/shot mixture in a circular path allowing the heavier full-size particles to exit for re-use. The smaller broken light-weight particles are extracted and sent to a waste barrel. The bucket elevator type system will spread the shot out to a long narrow curtain allowing it to fall past an air stream that is intended to attract the small broken particles and dust and send them to the waste barrel. The good media is then returned to the shot hopper for re-use.

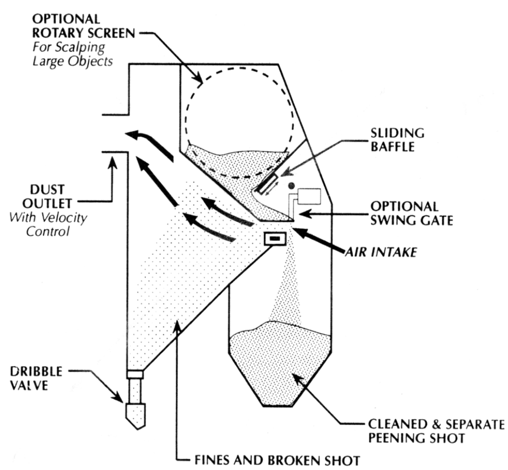

Figure 5. Air wash separator

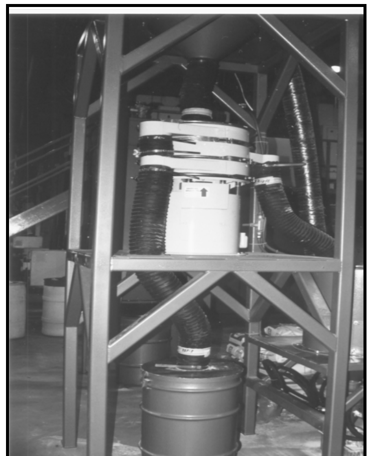
Figure 6. Screen separator

Either of the above systems can also utilize a screen separator system to provide a better segregation and elimination of the undersize media. A stack of screens, typically 36 inch diameter with the largest mesh size on top, is used to classify the shot by size. The top screen is used to divert any foreign material such as machine parts, paper and debris to the waste barrel. The next size screen, called the take-out screen, will allow the proper size media to be re-cycled to the shot hopper while the smaller shot particles drop through to be sent to the waste barrel.

3. Media

When we make dents we must use the proper media in order to obtain a smooth spherical impact. Broken media will tend to

Media must be spherical to make the proper shape (smooth) dent

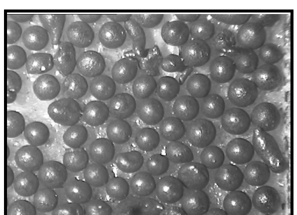
Figure 7. New cast steel shot

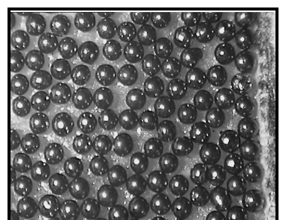
Figure 8. Used cast steel shot

scratch the surface and this could cause an eventual fatigue failure. Penning media is available in various types of materials, sizes and hardness. The most popular material is cast steel shot. Molten steel is poured from a vessel and hit with a stream of water that causes the steel to atomize and form small spheres. These spheres are then passed through screen separators to be classified by size to meet SAE industry standards. Cast steel shot will eventually fracture upon repeated impacts and must be removed from the machine. SAE tables will indicate the acceptable number of fractured particles allowed in a sample inspection as well as the percentage of media that must be retained on an inspection sieve screen.

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Figure 9. As-cut wire

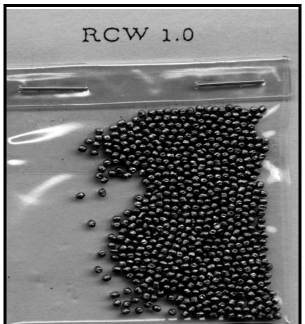

Figure 10.
Conditioned cut wire

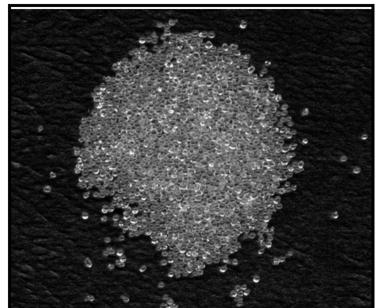

Figure 10. Glass bead

Cut-wire shot, available in regular carbon steel or stainless steel, is made by cutting wrought wire to a length equal to its diameter to form a small cylinder which is then thrown against a hard steel plate to convert it to a spherical shape. Cut wire shot does not fracture but does eventually wear down in size. The SAE inspection of cut wire shot requires weighing 50 pieces. Inspection for shape is also required to prevent use of any un-conditioned cut wire cylinders.

Glass bead and ceramic bead is also used in peening, especially at the lower intensities. Inspection intervals for these media are increased because of their relatively short lifetime before fracture. These media may be preferred on certain parts because they do not introduce any ferrous dust contamination that might result in rust.

4. Intensity

When we make dents they must be the right size to get the intended plastic zone that we want under the surface. The size of the dent is mostly controlled by what we call the “Intensity” and intensity is primarily controlled by the shot velocity and also its impact angle. Since we cannot easily measure the shot velocity as it exits the nozzle we must use a sample test coupon developed by J. O. Almen. Almen’s coupon, called an Almen strip, is a precision flat steel spring that is peened on one side causing it to curve in response to the shot stream intensity. By measuring the curvature, or arc height, we can interpret a relative intensity of the shot blast stream.

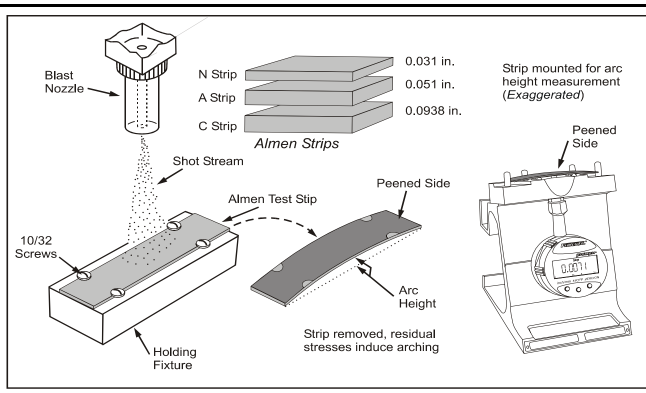

Figure 11. Intensity measurement procedure

Almen was an engineer at Buick Motor Division of General Motors Corporation and wanted a systematic way of performing shot blasting (as it was then called). He was aware of distortion caused to thin sheet metal when blast cleaned and adopted this test to peening. As a test coupon is blasted it will curve as a result of the stretching action caused by the dents on the top surface. As more dents are accumulated more stretching and hence curving will result. Eventually the surface becomes saturated with dents and only slightly more curving will result with additional blasting. By constructing a graph of the amount of curvature as a function of blast stream exposure time one can quantify the blast stream energy. Each setting of shot size, hardness, air pressure etc will result in a different curve on the graph.

But, now that we have a graph, what do we do with it? It's time consuming to construct a detailed graph and it doesn't appear to have an analytical value. A special procedure was created to allow us to read the graph and assign a value to the blast stream energy or intensity. Although the graphs appeared to level off or show saturation they never seemed to go completely flat. And even if they did it took an extraordinarily long time to do so. A compromise was made and it was decided to use the knee of the curve where the slope changes drastically as a reference point called "Intensity". The test has come to be known as the "10% doubling rule. This point on the curve is determined by estimating its location and then testing with the following criteria: if the arc-height rises only 10% more when doubling the exposure time then your estimate is correct. This point on the curve may, or may not, be exactly at one of your data points although it is often convenient to choose data points as the test. This point, in addition to being called the "Intensity" of the blast stream has also come to be known as "saturation" but this is an unfortunate choice of words. If the strip were "saturated" then it couldn't rise an additional 10%. Furthermore this term implied completeness and was the time to reach "saturation" was then deemed to be appropriate time for peening the actual workpiece. In Almen's day this may have been ok since the parts they were peening were valve springs of the very same material as the Almen strip. However is was soon discovered that peening was good for a whole host of components, some much harder and some much softer than the Almen strip. Most, but not all, practices specifically direct the operator to determine the proper exposure time by examining the surface of the actual work piece, or a simulated workpiece, for extent of coverage.

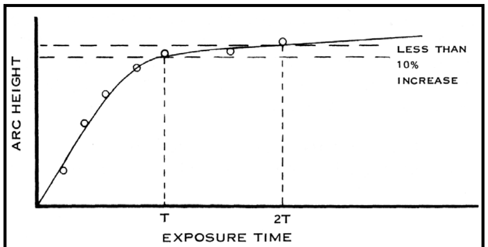

Figure 12 Intensity saturation curve

5. Coverage

A peened surface is said to be completely covered when only 2% or less of the original surface is left un-dented by the shot impacts. This 98% coverage of the surface is also referred to as full coverage or 100% coverage and it is verified usually with the aide of a 10x magnifying lens. With a little practice one can easily ascertain degree of coverage with a high degree of accuracy. It is important to examine the actual workpiece (instead of an Almen strip) for several reasons. First, the hardness of the workpiece may be different than that of the Almen strip. Next the actual treatment, angle of impact, flow rate, nozzle positions etc. may affect the surface denting. Determination of peening dents on very hard materials, such as hard gears may be especially difficult and a 20x or 30x lens may be required. This might also be the case for very low intensity peening, even on soft materials.

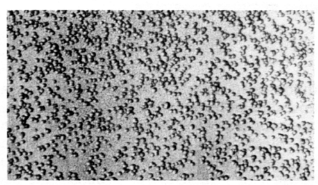
Figure 13. Partial coverage


Figure 14. Full Coverage

Several techniques have been developed to help the coverage inspection. Blue dye applied to the surface prior to peening will help give visual discrimination to the dents. Another useful aide is a special flourescent paint applied to the part surface prior to peening. After the paint is allowed to dry it is examined under ultra-violet (black) light to assure complete uniform coating. The part is then submitted to the blast stream and then re-examined under the black light. Any flourescent paint remaining indicates areas not struck with shot and hence incomplete coverage. You should examine the peened surface with the 10x lens to verify that the removal of the paint and actual surface denting are both occurring. It is possible that small broken shot or re-bound ricochet shot might remove the paint but not leave a proper dent in the surface.

Many peening drawings will request coverage of 200% or even 300%. This is a result of the earlier practice of using the Almen strip saturation time as a means of determining part peening time. It might have been appropriate for the valve springs made from the same material as the Almen strip but it certainly has limited valid use today. As you may recall the Almen strip saturation time occurred at a point on the curve where additional peening (another 100%) would cause the strip to rise by another 10% arc-height. If you used the “saturation” time as 100% then requesting another 100% for 200% coverage would get you to the final arc-height of the Almen strip. Modern peening practice (see SAE J443 and SAE J2441) have replaced the above confusion with a much simpler method.

You first determine the correct peening intensity using the Almen strip. Next you experiment with exposure times to ascertain the correct treatment to obtain 100% coverage. Some materials that are sensitive to work-hardening can be damaged by over-peening. Soft Aluminum, which covers much faster than the Almen strip due to the large size of the dents, can easily be over-peened if you base the exposure time on Almen strip performance. There are many materials that respond quite nicely to less than 100% coverage, meaning that a significant fatigue life increase will result even from 50% coverage. Tests should always be conducted to determine the proper intensity and the degree of coverage for each particular part to be peened. When in doubt use 100% coverage and consult the table in appendix A. for reference.

6. Controls

The control of peening falls into two basic categories, media condition and media delivery (propulsion). The condition of the media is inspected for size using standard test sieves. A 100 gram sample of media from the machine is placed on a sieve screen and it is shaken and tapped for approximately 15 minutes to allow all of the small particles to fall through the screen. The remainder particles are then collected and weighed and compared to the appropriate shot size table, see appendix B. for more details.

Figure 15 Sieves for size inspection

Figure 16. Particle fracture count

Another test for media condition is shape inspection. A representative sample of media is placed in a test pattern, usually 1x1 inch square, and the broken or deformed particles are counted using a top-lighted 20x binocular microscope. This is also called fracture count. Refer to the proper shot tables for the allowable number of fractured particles allowed, usually 10% or less. See appendix C. for more details.

The propulsion of the media is controlled by the speed of the throwing wheel or the air pressure of the nozzle system. Both of these can be, and should be, monitored with alarms. The amount of the media thrown, which directly affects the coverage, can be controlled by monitoring the throwing wheel amperage or the nozzle shot flow rate using MagnaValves or other suitable sensors.

7. Audits

Audits of shot peening operations are conducted to ascertain that the proper peening treatment is being applied by qualified operators and that adequate records are maintained. The following questions are likely to be asked during an audit.

1. What is your authority to peen? What shop orders, technical directives, specifications are you supposed to be using? Show them to me.
2. What shot size, peening intensity, peening coverage and location is required?
3. How often do you inspect your media for size and for shape? Show me how you do it and show me your records.
4. How often do you perform peening intensity checks? Show me how you do it and show me your records.
5. How often do you perform coverage inspection? Show me how you do it and show me your records.
6. How do you treat non-conforming parts? What do you do when an alarm condition aborts the machine cycle?
7. Do you run a new saturation curve for any of the following events?
    A. Media size violation
    B. Media shape violation
    C. Nozzle or blast hose repair or replacement
    D. Throwing wheel repair or replacement
    E. New set-up (different nozzle aiming or different fixtures).
8. Are your Almen gages, holders and strips and sieve screens certified (current)?
9. Are your operators trained and tested by a recognized organization? Are they due for re-training or advanced training?