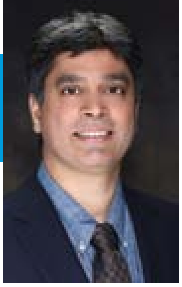

**AN INSIDER'S PERSPECTIVE**
*Kumar Balan | Ervin Industries, USA | kbalan@ervinindustries.com*

# The Critical Role of Metallic Shot in Achieving Consistent Shot Peening Results

**Introduction**

The quality of metallic shot plays a critical role in the accuracy and repeatability of shot peening results. Energy transmitted from the shot to the component determines the residual compressive stress, and the fatigue life developed in the component. The two key measures of the value and quality of metallic shot are: Durability (life) and Transmitted Energy (Impact Energy).

The other characteristics such as size, hardness, microstructure, and physical defects including cracks, shrinkage, voids, and chemical analysis, also have a bearing on the effectiveness with which the energy is transmitted.

Process specification for a component to be shot peened will stipulate the shot size, type, and sometimes its hardness. As for the shot quality, the shot peener is completely reliant on the shot manufacturer's self-certification process to ensure its conformance to appropriate SAE or AMS requirements. To validate metallic shot quality, the Ervin Test Lab regularly runs tests of shot samples for the above parameters and evaluates performance using SAE J445.

Compilation of such data through analysis of 37 different samples of non-Ervin manufactured metallic shot in 2016 revealed that over 40% of the samples showed low performance, which was the direct result of specification deficiency in these samples, as required by SAE J827, SAE J444, AMS 2431/1 or AMS 2431/2. Not being able to reliably transmit the intended impact energy defeats the purpose of the process. The information discussed in the paragraphs that follow is intended to provide the reader a procedure to test the two critical parameters—Durability and Transmitted Energy of metallic shot peening media.

**Objectives**

1. To offer a test procedure for assessing metallic shot durability (to predict life cycle before spherical, peening shot breaks down and is no longer useful for peening)
2. To offer a test for calculating transmitted energy in a test machine using Almen A strip
3. To discuss the effects of microstructure and physical defects on peening results

**Methodology – the Ervin Test Machine**

The optimum way to test the durability of the shot would be to process it through a production-style blast wheel and study its breakdown characteristics. However, the nature of the process and the inability to precisely capture the shot make that exercise impractical. The Ervin Test Machine was designed to simulate the action of a production blast cleaning or shot peening blast wheel machine, and at the same time, provide a laboratory (and portable) tool to quickly test the performance (durability and transferred energy) of metallic shot.

In the Ervin Test Machine, the centrifugal wheel (commonly referred to as "beater") is driven at 7,000 RPM by an electric motor to generate a velocity of approximately 200 feet per second. This is within the range of velocity developed in a production machine. Metallic shot introduced into this wheel is impacted against an anvil surface. After impact, the shot falls to the bottom of the rotating anvil recycling assembly which picks it up and returns it to the wheel from where it is repeatedly thrown against the anvil surface. The anvil recycling assembly rotates at 25 RPM resulting in the shot being recycled through the wheel 25 times per minute. This arrangement is used for testing the Durability, and with


*The Ervin Test Machine*

a minor change in set-up, the Transmitted Energy. When testing for Transmitted Energy, the Anvil is replaced with the peening attachment which holds an Almen "A" strip in the impact path of the metallic shot being tested.

**Test Procedure (for Durability)**
**Described for S-550 Amasteel Shot**

1. Remove the plug/cork and add an accurately weighed 100 ± 0.1 gram sample of S-550 into the anvil/recycling device. Seal the opening with the plug/cork.
2. Set the counter for 500 cycles.
3. Turn the machine on. The counter will stop the machine after 500 cycles.
4. Empty the shot into the tray provided, ensuring that the contents are removed when the plug is pulled out. Rotate the anvil/recycling device multiple times while steadily rapping the housing with a plastic hammer.
5. Place the sample on an 8" diameter, 40 mesh, 0.0165" opening test sieve and screen the sample for about three minutes. This will remove all the fines from the metallic shot.
6. Weigh the amount of sample remaining on the test sieve and record it as "% Retained".
7. Calculate the Loss, 100% minus weight from (6) above and record the value as "% Loss."
8. Replace lost material with new sample shot until the weight adds up to 100 ±0.1 grams.
9. Repeat steps 1 through 9, regularly adding the % Loss from each 500-pass test run into a new column titled "Accumulative % Loss" until the "Accumulated % Loss" exceeds 100%.
10. Determine the durability, or number of cycles/passes for an exact 100% replacement by interpolation using the following formula:

Durability = Total Passes – (passes per test run/% last lost)
(accumulative % loss – 100)

In this example, the durability works out to 3050 cycles or passes of the metallic shot.

***Note:*** *The Ervin Test Machine is most effective for testing metallic shot sizes S170 and larger.*

The information is presented in Table 1.

Key observations from the data and result above:

- The inference is based on a specific set of process parameters, particularly the shot velocity. The speed was chosen as 7000 RPM to optimize the shot velocity around 200 feet per second, to approximate that normally generated by a blast wheel.
- The calculated life cycle of 3050 is an absolute number until compared to metallic shot from an alternate source (competition), but using the same manufactured parameters (size, hardness, etc.).
- Breakdown of the shot in Table 1 demonstrates a uniform and steady pattern throughout its life cycle. The absence of any spikes or radical drops proves the integrity of metallic shot and its natural wear rather than abnormalities that would point towards physical defects such as cracks, shrinkages and voids.
- The steady breakdown also leads us to comment on its microstructure. A highly controlled atomization process is paramount to building a refined and uniform microstructure with minimal voids and other grain imperfections. Additionally, such a breakdown pattern could also mean that the microstructure is free from brittle iron carbides that lead to premature shot fracture.
- The life cycle test provides a good predictability measure as to when the shot will start downsizing due to normal wear and the subsequent potential for erroneous results. These observations need to be understood with the degree of caution that SAE J445–Metallic Shot and Grit Mechanical Testing directs us to, stating that the data from the tests is suitable to check the "uniformity of shot shipments or to determine the relative fatigue life," and not to obtain operating costs. This is because field conditions are different from the test lab. In other words, factors such as machine maintenance, hardness of the component being blasted/peened, metallic shot size, hardness, etc., also have a role to play in shot breakdown.

**Table 1: 100% Life Test**

| Cumulative Passes | % Remaining | % Loss | Accumulative % Loss |
|---|---|---|---|
| 500 | 91.8 | 8.2 | 8.2 |
| 1000 | 86.0 | 14 | 22.2 |
| 1500 | 83.3 | 16.7 | 38.9 |
| 2000 | 78.2 | 21.8 | 60.7 |
| 2500 | 80.6 | 19.4 | 80.1 |
| 3000 | 81.8 | 18.2 | 98.3 |
| 3500 | 83.1 | 16.9 | 115.2 |

**Test Procedure (for Transmitted Energy)**

1. Obtain a 50.0 ±0.1 gram sample of the used metallic shot from the Durability Test conducted earlier.
2. Put this sample in the test machine.
3. Fix an Almen A strip on to the peening attachment.

The peening attachment matches the test strip holder as specified in SAE J442, with an additional attachment on the back to mount it in the test machine.

4. Peen the Almen strip for 40 cycles (this is assumed to be the point of saturation of the strip) and then measure the arc height.
5. Measure the arc height using an Almen Gage. The resulting value is a measure of the Transmitted Energy.

The two tests described above are identified in SAE J445. For the Durability Test, SAE J445 describes two other techniques: 5.2: Average Life by Measurement of the Area Under the Breakdown Curve and 5.2: Stabilized Loss Method. The Durability Test described here is listed as 5.3: 100% Replacement Method in the specification.

**Other Lab Tests**

In addition to the above, the metallic shot is subjected to additional tests at the Ervin Lab.

**Hardness** – This test uses a 1000 gram load.

The test procedure for hardness consists of testing ten different grain samples gathered and positioned in a Bakelite base. These samples are ground to half their diameter so that the center of the grain is tested for its hardness. Based on such a test, the maximum and minimum hardness were 45.5 Rockwell C and 41.9 Rockwell C respectively, for an average hardness of 44.3 HRC. The readings reveal clearly that this is a sample from the standard hardness range of 40 to 51 Rockwell C (SAE J827). In shot peening, the shot hardness is generally the same as or greater than the hardness of the part being peened. This is to ensure that the proper depth and level of residual compressive stress are generated in the part. If not stipulated in the peening specification, the common practice is to use standard hardness shot (40 to 51 Rockwell C – SAE J827 specification for standard hardness). Hard shot breaks down relatively faster and accelerates wear in the interior of the blast machine and wheel parts.

*Hardness Testing – Shot grains are captured in a Bakelite Base and ground to half their diameter. Hardness is tested at the center.*

**Chemical Analysis** – Table 2 below provides the results from Chemical Analysis on the test sample from before.

**Table 2: Chemical Analysis**

| Elements | SAE J827 | Amasteel S-550 |
|---|---|---|
| Carbon | 0.80 to 1.20% | 0.9 |
| Sulphur | 0.050% Max. | 0.02 |
| Manganese | 0.6 – 1.20% | 0.94 |
| Silicon | 0.40% Min. | 0.93 |
| Phosphorus | 0.050% Max. | 0.022 |

Key points from the above test results:

Chemical analysis and subsequent metallurgical adjustments during the melting stage influence the durability of the metallic shot.

- High carbon content results in brittle shot microstructure that contributes to early shot fracture and failure. Low carbon content, on the other hand, will cause the shot to absorb a large portion of the Kinetic Energy, resulting in reduced energy available for shot peening or blast cleaning.
- Sulphur and Phosphorus content should be minimal in the metallic shot. These elements weaken grain boundaries and lead to lower durability and transmitted energy of the metallic shot.
- Manganese content within the specified range is critical in influencing the durability of the shot.
- Silicon in higher percentages also contributes to high durability. Additionally, it also acts as a de-oxidising agent.

**Physical Defects**

Manufacturing methods commonly employed will result in a certain level of defects and SAE J827 lists the limits for the defects. The detrimental effects caused by these defects are reduced transmitted energy and premature breakdown. The shot sample above was observed under 10X magnification for the following results.

**Table 3: Objectionable Defects**
(Micro-Examination at 10X – SAE J827)

| | | |
|---|---|---|
| **% Voids** | 10% Maximum | 2.8 |
| **% Cracks** | 15% Maximum | 7.0 |
| **% Shrinks** | 10% Maximum | 0 |
| **% Elongated** | 5% Maximum | 0 |

## AN INSIDER'S PERSPECTIVE

*Continued*

**Summary**

The ideal metallic shot should be able to transmit the maximum impact energy on to the component being shot peened or blast cleaned. This in turn will provide the most economical cost of operation. Metallic shot with its chemistry within the range specified in J827, consistent hardness, defined microstructure and imperfections within allowable limits will provide optimum peening and cleaning results.

The techniques explained above are aimed at describing a method to test your new metallic shot and ensure that it conforms to required specifications (AMS or SAE) before being put to use.

**References**

[1] Ervin Industries Technical Bulletin (Vol No. VIII: Issue No. 6: July 2003, found on ervinindustries.com)

[2] Ervin Industries Technical Bulletin (September 2003)

[3] Ervin Industries Lab Test Data

[4] Ervin Test Machine Technical Data

[5] SAE J445 Metallic Shot and Grit Mechanical Testing (Rev. Apr. '96)

[6] SAE J827 High-Carbon Cast-Steel Shot (Rev. Sept. '96)

**Acknowledgement**

I would like to thank Denny Shearer, Technical Services Manager, Ervin Industries, and Joe McGreal, Vice President Sales and Marketing, Ervin Industries. They helped with the content and review of the article. Their decades of experience in the industry helped validate the information presented here.

**PEENSOLVER**

**Your Free Curve Solver Web App**

**Download it at**

**www.peensolver.com**

Peensolver calculates peening intensity as defined in SAE J443. It also conforms to SAE J2597. It evolved from the Curve Solver spreadsheet program developed by Dr. David Kirk that is widely used around the world. Like Dr. Kirk's program, it generates a fitted curve through the given data points. Using the corrected arc heights from the curve, it then locates the one arc height that increases by 10% for the doubling of exposure time. This arc height is the intensity value.