Technical Bulletin

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VOLUME NO. VIII: ISSUE No. 6
JULY 2003

Shot Quality and How To Select Shot for Peening

This discussion of shot must first be preceded by a brief discussion of the basics of shot peening in order to lay the groundwork for shot selection.

THE BASICS OF SHOT PEENING

In shot PEENING, kinetic energy is imparted to a shot particle by a centrifugal wheel or compressed air. The kinetic energy of the flying particle impacting against the part to be shot peened, causes elastic and plastic deformation of the part surface. The unrecovered compression of the part surface results in beneficial residual compressive stresses remaining in the topmost surface layers of the part being peened and extending to some depth below the surface. Since all fatigue failures are caused by surface tensile stresses, usually resulting from the application of a cyclic load, this surface layer of residual compressive stresses effectively delays the onset of fatigue failure of the part. The magnitude of residual compressive stresses produced by shot peening is the result of many peening parameters, including shot characteristics, and is typically controlled by the use of Almen Test Strips.

BASICS OF SHOT FOR SHOT PEENING

As can be seen from the above description of shot peening, the quality of the shot used is key to an efficient, effective and economical operation. Up to the point of impact with the part surface, all types and quality levels of shot, of the same size, are identical. It is at the instant of impact on the part surface that the quality and makeup of the shot particle must efficiently transmit this kinetic energy into the part surface to produce the beneficial residual compressive stresses.

How efficiently this energy is used to do useful work is dependent on the following shot characteristics:

1. Hardness
2. Microstructure
3. Physical Defects (cracks, shrinkage voids)
4. Chemical Analysis
5. Size
6. Fatigue Life (durability)
7. Transmitted energy

HARDNESS

The standard hardness range for cast steel shot and grit is 90% minimum 41-51 HRC which is designated S hardness for Amasteel Shot and Grit. There are several other different hardness ranges of shot specified to accomplish different peening requirements. Some of the standard hardnesses of Amasteel Shot are M, 47-56 HRC, L, 54-61 HRC, and H, 60 minimum HRC. AMS 2431/1C specifies 45-52 HRC and AMS 2431/2C specifies 55-62 HRC.

If the abrasive is too soft, a large portion of the available kinetic energy is absorbed by the abrasive particle as it flattens against the workpiece surface. This kinetic energy is lost and is not available for shot peening resulting in slower coverage and lower arc heights. The hardness of shot for shot peening must be approximately equal to the hardness of the work being peened. Shot that is too soft will not produce the proper level or depth of residual compressive stresses. The effect of low hardness shot cannot be compensated for by increasing peening cycle times.

Harder shot breaks down more rapidly and usage rates increase. Sometimes low peening results are caused due to excessive fines resulting from the rapid breakdown if broken shot removal is not closely controlled. Harder shot creates more extensive wear in the machine, increasing maintenance costs.

Microstructure

The microstructure of the shot must be such that the shot will resist deformation as it impacts against the surface of the workpiece, which maximizes the energy loss and gives maximum shot fatigue life. Tempered martensite is the most fatigue resistant microstructure available in shot on the market today. In addition, the microstructure must be free of brittle iron carbides which contribute very strongly to premature shot fracture and high shot usage rates.

Physical Defects (cracks, shrinkage, voids)

The shot must be as free as possible of physical defects that may contribute to the fracturing of the shot and the attendant high usage rates. All shot manufactured today will have a certain number of these defects due to the methods of manufacture used. Application of Statistical Process Control will minimize the number of shot particles with these objectionable defects.

Chemical Analysis

Chemical Analysis is very important to controlling microstructure. In addition, high carbon content contributes to early particle failure due to the formation of weak, brittle, grain boundary iron carbides. Carbon content that is too low produces a shot that will deform and absorb energy as discussed under hardness, above. Sulfur and phosphorous content must be kept as low as possible since both contribute to early fatigue failure and is well documented in metallurgical texts.

Size

Shot size is very critical. Every shot peening machine propels a constant number of pounds of shot per hour, which is dependent upon the horsepower of the centrifugal wheel or the volume of air used per hour in an air blast machine.

The number of particles in a pound is therefore a function of the particle size.

A pound of S-660 shot contains 14,000 particles. A pound of S-330 (half the diameter of S-660) contains 110,000 particles, 8 times as many as S-660. Therefore a wheel that throws one pound, would throw 14,000 impacts of S-660 or 110,000 impacts of S-330. Conversely 1 particle of S-660 would have 8 times the impact energy of 1 particle of S-330, due to the $E = 1/2MV^2$ kinetic energy formula.

However, a small shot particle may not possess sufficient energy to peen effectively and produce the compressive stresses to the depth required.

It is important to select the smallest size of shot that will produce the proper Almen intensity since small shot will saturate the surface more rapidly. The purpose of this size discussion is to point out the tremendous increases in speeds possible by using the smallest size of abrasive that produces adequate cleaning or shot peening. Processing time is money and fast coverage will reduce cost.

Fatigue Life (durability)

Fatigue life or durability is the ability of the shot to resist failure or breakdown due to the impact of the shot on the workpiece. The shot with the greatest durability will be the most economical abrasive to use if it has the ability to transmit adequate energy to clean or shot peen.

Transmitted Energy

The ideal abrasive must be able to transform the maximum amount of kinetic energy to the surface of the workpiece to be shot peened. Shot that deforms and absorbs energy at impact such as the example of low hardness above, will take longer to peen due to the amount of energy lost through shot deformation. Therefore, the most economical shot for shot peening will transmit the most kinetic energy to the workpiece surface, as measured by Almen arc height produced under identical conditions of exposure. The Ervin Test Machine and standard test procedures are available to test shot durability and transmitted energy on small scale, laboratory basis.

SUMMARY

The shot that transmits the greatest amount of energy to the workpiece with the greatest fatigue life will produce the most economical and consistent shot peening operation. Shot with proper hardness, microstructure, chemical analysis, size, and a minimum of physical defects will contribute to greater transmitted energy and fatigue life.

Shot should be purchased to conform with standard industry specifications. SAE J827 and J444 are adequate specifications to be used for most production shot peening applications, for shot with a hardness range of 41-51 HRC. Shot can be ordered to these SAE specifications but with special hardnesses in any range with a spread of about 6 HRC for 90% of the shot particles.