AN INVESTIGATION OF THE DURABILITY AND BREAKDOWN CHARACTERISTICS OF SHOT PEENING MEDIA

R. D. Gillespie, Premier Shot Company, Cleveland, Ohio, USA
H. Gloerfeld, KME, Iserlohn, FRG

ABSTRACT

The beneficial effects of shot peening in extending fatigue life has become quite well known in the metals field. Today's engineers are becoming more and more dependent on shot peening to provide resistance to fatigue failures in cyclically loaded parts. Certain fatigue critical components must have proper shot peening in order to meet their minimum life requirements. The first item needed to provide high quality shot peening is a high quality peening media.

However, recent technical data investigating important properties of commonly used shot peening media is not readily available. This paper discusses these properties: size, shape, hardness, density and durability (Useful Life and Resistance to Fracture) of commonly used shot peening media. Also discussed is each media's potential for creating surface damage caused by impact of sharp edged or broken particles.

The media exhibiting the best properties in all six categories is wrought steel shot.

KEYWORDS

Wrought steel shot; cast steel shot; ceramic shot; glass beads; size; shape; density; hardness; durability; Useful Life; Resistance to Fracture; surface damage.

INTRODUCTION

The purpose of this paper is to study, and evaluate, various shot peening media. The most common media in use today for shot peening applications are made from four materials: wrought steel, cast steel, ceramic beads and glass beads. In order to evaluate the merits of shot peening media, Premier Shot Company (PSC) performed a study which included the above four materials. Prior to this study, PSC considered the important variables affecting the shot peening process.

Maximum work that can be done by any piece of shot cannot exceed its Kinetic Energy (KE). The engineering formula for KE of a moving particle is $KE = \frac{1}{2}mv^2$ where m is the mass of the particle and v is its velocity. Of the two variables in the KE equation, mass is dependent on the properties and characteristics of the shot itself. Velocity is dependent on the shot peening process variables such as wheel speed, air pressure, shot flow rate, nozzle size, etc. The mass of a piece of shot is the product of its density and its volume. Density depends on the material from which the shot is made and the processes used in the manufacture of the media. Volume of a shot particle is a function of its size and shape.

Also important is shot rigidity, or hardness. During a collision of two objects, the less rigid, or softer object, will absorb the most energy or work. This is the reason that it is recommended to shot peen with a media equal to or harder than the part being peened (Ref. 1). Otherwise, the majority of the work transmitted during the collision would be back into the shot itself rather than into the workpiece.

Finally, one must consider the durability of peening media, or how the shot will maintain its size and shape during use.

For this study PSC will confine our evaluation of different media to the properties that effect the peening process most: size, shape, hardness, density and durability (Ref. 1).

Each media has its own unique size and hardness ranges. It was necessary, in order to make comparisons between the media, to select a common size and hardness range. Most shot peening is done with media between 0.2mm and 2.0mm in diameter. A size in the middle of this range and that was available in all four media was selected - 16 mesh to 20 mesh. These mesh designations are U.S. Standard Sieve sizes corresponding to 0.0467 inch (16 mesh) and 0.0331 inch (20 mesh) sieve openings.

There was no single hardness range compatible with all four media. The range HRC 55-65 is available in wrought steel, cast steel and ceramic shot. The range HRC 45-55 is available in wrought steel, cast steel, and glass beads. Glass beads are known to be the least durable of the four media. It was determined that using the hardness range HRC 55-65 would provide a direct comparison between the three more durable media. The durability of glass beads in a hardness range of HRC 55-65 is expected to be even lower than that measured during this program. Since the durability of the HRC 45-55 glass beads was lower than any of the harder media, the ranking of the media according to durability is not affected by using the softer glass beads.

It should be pointed out that the wrought steel media (PCW 35) used on this test program was conditioned (rounded) cut wire shot. Shot peening should always be performed with conditioned cut wire shot. If unconditioned cut wire cylinders are used, possible surface damage can be done by the sharp edges of as-cut cylinders as we will see later in this paper.

Size

The following are comparisons made from specifications for new (unused) media. The respective size ranges of each media are shown in Table I. Two differences are quickly apparent:

1) Cast Shot - The minimum percentage of media between 16 and 20 mesh is 88% for cast steel shot compared with 85% for the others.

2) Wrought Shot - 85% of the wrought media is between 18 and 20 mesh compared with 16 and 20 mesh for the others.

In order to compare the different media, it was decided to use cast steel shot, the most commonly used media for shot peening, as a base for each evaluation. Cast steel shot rating will always be one (1.00). The other media ratings will be either a multiple of the cast steel shot value in the cases where the other media is better than cast shot or a fraction of the cast shot value where the other media rating is lower. (Example #1: 88% is the allowed percentage for cast steel media and 85% is the allowable percentage of the other media. Cast shot would have a rating of 1.0 and the other media would have ratings of 85% divided by 88% = 0.97. Example #2: The allowable size of the 85% of the wrought media is between 18 and 20 mesh - a 0.0063 inch range. The allowable size of the other media is between 16 and 20 mesh - a 0.0138 inch range. The wrought media rating would be 0.0138 divided by 0.0063 = 2.19). Glass and ceramic beads have the same range as cast shot and would, therefore, have a rating of 1.00. A Combined Rating is obtained by multiplying the two individual ratings (Minimum Percent Allowed and Nominal Size Range). The combined rating for the size of PCW 35 is 0.97 x 2.19 = 2.12. A comparison of size of the four media is shown in Table II.

Shape

To make a comparison of the shape of the various media, the allowable number of unacceptable particles was used. Maximum number of unacceptable particles are included in almost all specifications for shot peening media. Unacceptable particles are: hollow, cracked, deformed, broken, sharp edged, nodulated or twinned particles. A comparison of maximum allowable unacceptable particles from commonly used specifications is shown in Table III. It is evident the wrought steel media (PCW 35H) has the best shape rating; followed by ceramic, glass and, finally, cast steel

Hardness

It is important to peen with a media at least as hard as the workpiece.

Comparison of the hardness ranges of the four media is shown in Table IV. Since all peening media has a hardness range, or ranges, our comparison was made in terms of the size of commonly used and accepted ranges. The wrought (cut wire) media is controlled by the tensile strength of the wire used to manufacture the shot. Typical tensile strength values for carbon steel cut wire are plus or minus 20,000 pounds per square inch or +/- 150 N/mm^2 (Ref.2). Hardness values for the wrought conditioned cut wire shot are plus/minus HV30 (Ref. 6). Conversion to Rockwell C hardness for all media was done using the conversion table in ASTM A370 (Ref. 3).

Density

Because the potential work that can be done by a moving shot particle increases with increasing density, a comparison of the minimum allowable densities of the various media is included. Densities for the subject media are also given in Table IV.

Durability

For purposes of evaluation, durability of each media was separated into two areas: Useful Life and Resistance to Fracture.

Useful Life of peening shot can be defined as the total number of cycles the shot can endure before it is no longer acceptable sized media. Evaluation of Useful Life is a relatively simple test (Ref. 4). A representative sample of the media to be tested is propelled against a target at a constant speed, impingement angle, and distance from the target. The media is then collected and recirculated back into the test machine and propelled against the target again. Each pass of the sample through the test machine is counted as one "peening" cycle. A test curve can be drawn which plots the cumulative amount of media remaining on a specified test sieve (20 mesh for the sizes of shot tested in this study) against the cumulative number of cycles of the test (Fig. 1). The point at which 100% Breakdown (number of cycles that completely breaks down the initial charge of shot) occurs is the Useful Life of the media. Table VI compares the Useful Life at 100% Breakdown of the four media of this test program. Media that has deteriorated to an unacceptable size will not have sufficient mass to produce the desired peening result.

Resistance to Fracture of peening shot is of equal importance to Useful Life. Simpson and Chaisson (Ref. 5) showed that impingement by sharp edged broken particles can create damage on a peened surface which can lower cyclic life below that of unpeened material. Figures 2 and 3 clearly show surface damage caused by broken shot. Comparison of the Resistance to Fracture (RTF) of the media in this program is given in Table V. In order to determine the RTF of the test media, ten 12.5mm by 12.5mm (the area recommended by most specifications for evaluation of unacceptable particle count) fields were evaluated at the Useful Life (at 100% Breakdown) of each media. The total number of unacceptable particles counted in the ten fields are reported in Table V. Scanning Electron Microscope (SEM) photographs of each media are shown in Figures 4, 5, 6 and 7. Broken particles are apparent in all media except the wrought carbon steel media. Wrought shot exhibited virtually no broken particles. The potential for surface damage caused by impact of broken or sharp edged particles is greatly reduced when using wrought steel media. It should be stressed that the number of cycles used for each media in Figures 4, 5, 6 and 7 was its Useful Life (PCW 35 - 2636 cycles, CS330 - 634 cycles, Z 850 - 7 cycles and GB 100 - 2 cycles).

It should be pointed out that the above durability testing was done in a machine that propels the media against a hardened target at a constant speed (approximately 185 meters per second), at a constant distance from the target and at a constant impingement angle. These same conditions were used for all media tested. The only change in each test was the media itself. Changes in the speed, distance, impingement angle or target material may result in different Useful Life and RTF values. However the relative ranking of the media is expected to remain the same. Wrought steel shot should exhibit the highest Useful Life and Resistance to Fracture and the glass beads the lowest.

SUMMARY

A summary of the comparative ratings of wrought steel, cast steel, glass beads and ceramic beads is presented in Table VI. Each category discussed in this paper is listed. The media that displayed the best properties in each category is given a rating of A and the media displaying the lowest properties is rated D. The second best media is rated B and the next to last media would have a C rating. It is quite clear that the only media to rank best (A) in all six categories is the wrought steel media. The wrought media showed the best consistency in size, shape and hardness. Wrought shot also exhibited the highest density and, by far, the best durability (both Useful Life and Resistance to Fracture)..

REFERENCES

(1) "SAE Manual on Shot Peening - SAE 808a". SAE Information Report HS 84, 1967 Edition. SAE, 400 Commowealth Drive, Warrendale, PA, 15096.

(2) "Cut Wire Shot - SAE J441". SAE Materials Practice, May 1987. SAE, 400 Commonwealth Drive, Warrendale, PA, 15096.

(3) "Standard Test Methods and Definitions for Mechanical Testing of Steel Products - A370-87b". ASTM, 1916 Race Street, Philadelphia, PA, 19103.

(4) Gillespie, Bob, "Durability Comparison - Wrought Steel Shot vs Cast Steel Shot". The Shot Peener, Volume 3, Issue 2, 1989.

(5) Simpson, R.S., and Chaisson, G.L., "Quantification of the Effects of Various Levels of Several Critical Shot Peen Process Variables on Workpiece Surface Integrity and the Resultant Effect on Workpiece Fatigue Life". U.S Air Force Wright Aeronautical Laboratories, AFWAL-TR-88-3029.

(6) "Metallic abrasives, cut wire pellets; Quality requirements, tests. - VDF 8001". Verband der Deutschen Federnindustrie, Hagen, December, 1982.

(7) "Peening Media, Cast Steel Shot, Regular - AMS 2431/1". Aerospace Materials Specification, 4-1-88. SAE, 400 Commonwealth Drive, Warrendale, PA, 15096.

(8) "Peening Media, Cast Steel Shot, Hard - AMS 2431/2". Aerospace Materials Specification, 4-1-88. SAE, Commonwealth Drive, Warrendale, PA, 15096.

(9) "Shot Peening of Metal Parts - MIL-S-13165C". U.S. Military Specification, 7 June 1989.

(10) "Size Classification and Characteristics of Ceramic Shot for Peening - SAE J1830". SAE Recomended Practice, May 1987. SAE, 400 Commonwealth Drive, Warrendale, PA, 15096.

(11) "Peening Media, Ceramic Shot - AMS 2431/7". Aerospace Materials Specification, 4-1-88. SAE, 400 Commonwealth Drive, Warrendale, PA, 15096.

(12) "Size Classification and Characteristics of Glass Beads for Peening - SAE J1173". SAE Recommended Practice, January 1977. SAE, 400 Commonwealth Drive, Warrendale, Pa, 15096.

(13) "Peening Media, Glass Shot - AMS 2431/6". Aerospace Materials Specification, 4-1-88. SAE, 400 Commonwealth Drive, Warrendale, PA, 15096.

(14) "Steel Grit, Shot and Cut Wire Shot; and Iron Grit and Shot for Blast Cleaning and Peening - MIL-S-851D". U.S. Military Specification, 21 April 89.

Table I - Size Ranges

Material	Size Designation	Minimum Percent Allowed	Size Range
Wrought Carbon Steel	PCW-35	88%	-18/+20 mesh (Ref. 6)
Cast Carbon Steel	CS-330	85%	-16/+20 mesh (Ref. 7,8,9)
Ceramic Bead	Z-850	85%	-16/+20 mesh (Ref. 10,11)
Glass Bead	GB-100	85%	-16/+20 mesh (Ref. 12,13)

Table II - Size Comparison

Media	Minimum Percent Allowed	Rating	Nominal Size Range	Rating	Combined Rating
PCW-35	85%	0.97	0.0063	2.19	2.12
CS-330	88%	1.00	0.0138	1.00	1.00
Z-850	85%	0.97	0.0138	1.00	0.97
GB-100	85%	0.97	0.0138	1.00	0.97

Table III - Shape

Media	Maximum Percent Unacceptable Particles	Rating
PCW-35	0.5% (Ref. 6)	20.00
Z-850	2.0% (Ref. 10,11)	5.00
GB-100	3.0% (Ref. 12,13)	3.33
CS-330	10.0% (Ref. 9)	1.00

Table IV

	HARDNESS		DENSITY	
Media	Hardness Range (HRC Points)	Rating	Minimum Density (g/ml)	Rating
PCW-35	5 (Ref. 6)	2.00	7.8	1.11
CS-330	10 (Ref. 9,14)	1.00	7.0	1.00
Z-850	6 (Ref. 10,11)	1.70	3.6	0.51
GB-100	5 (Ref. 12,13)	2.00	2.3	0.33

Table V - Durability

	USEFUL LIFE		RESISTANCE TO FRACTURE	
Media	Life at 100% Breakdown	Rating	Number Unacceptable Particles	Rating
PCW-35	2636	4.158	1	24.00
CS-330	634	1.000	24	1.00
Z-850	7	0.010	70	0.34
GB-100	2	0.003	144	0.17

Table VI - Ranking

Media	Size	Shape	Hardness	Density	Useful Life	Resistance to Fracture
PCW-35	A	A	A	A	A	A
CS-330	B	D	D	B	B	B
Z-850	C	B	C	C	C	C
GB-100	C	C	A	D	D	D

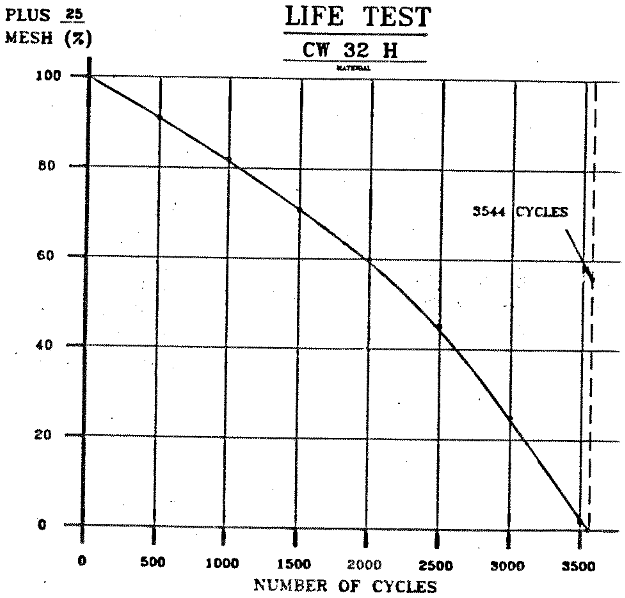

Figure 1: Useful Life Curve

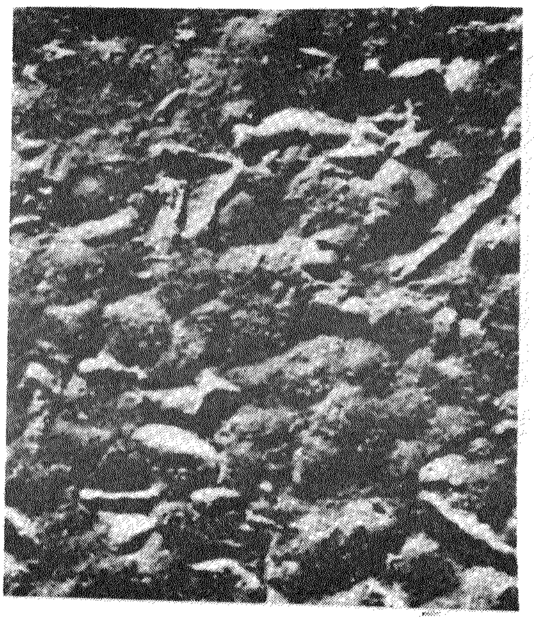

Figure 2: Surface Damage caused by Broken Shot on 7075T73
200x

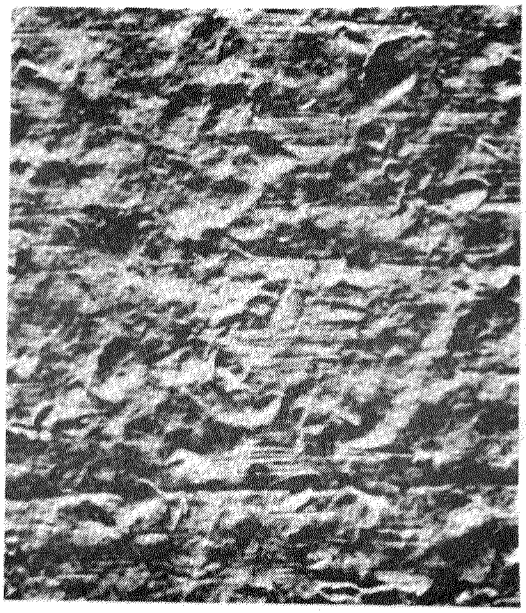

Figure 3: Surface Damage caused by Broken Shot on 4340 VAR Steel (HRC 48/50)
200x

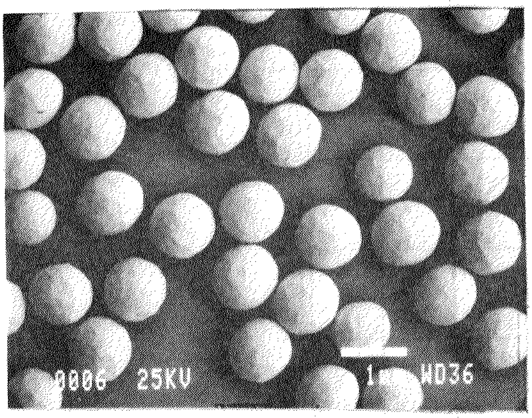

Figure 4: PCW-35H after
2636 cycles

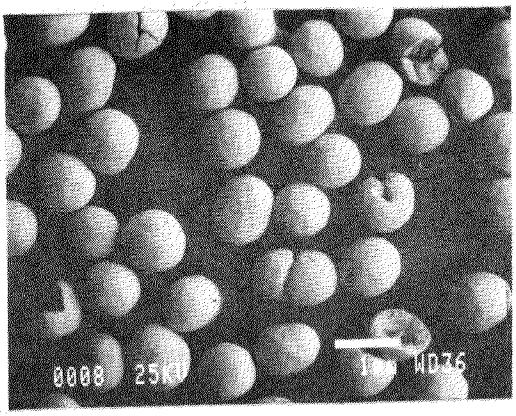

Figure 5: CS-330H after
634 cycles

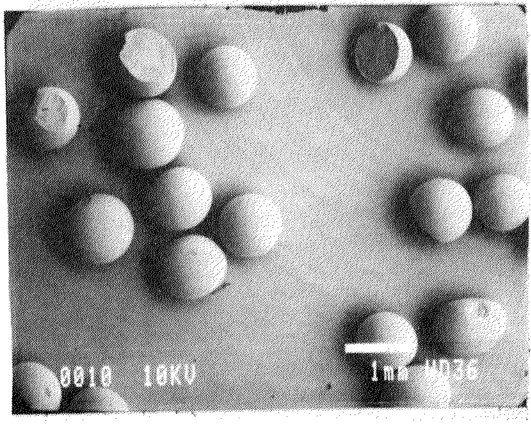

Figure 6: Z-850 after
7 cycles

Figure 7: GB-100 after
2 cycles