The Need for High Quality Shot for Peening

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ABSTRACT

Peening techniques demand higher standards from both process and media than is acceptable in other impact treatment operations. Choice of media type is dependent upon component composition, application and design criteria. The need for specially manufactured cast and cut wire steel products for this critical application is examined and justified based on the requirements of the process.

INTRODUCTION

The need for improvement in quality and scope of specifications for media to be used in general impact treatment processes is considered elsewhere. Peening media is developed from these basic products. Improvement in both definition and standardisation of abrasive quality specifications can, through reference, contribute to a similar improvement in revision of standards specifically relating to use of the products in peening techniques.

Cast-steel peening shot differs from standard abrasive quality material in a number of ways. The tolerances on size and shape are tighter. Hardness is generally specified within closer limits and to differing ranges. The normal single range of shot hardness offered for cleaning use is often not sufficiently high to ensure the desired peening effect is achieved on components which may be significantly harder.

In the case of cut steel wire media, where for normal cleaning the sharp-edged cylindrical form of wire may be used, in peening processes it is necessary to pre-condition and round the material before it is suitable.

CHOICE OF MEDIA

The two basic classes of shot used in peening processes are glass beads and steel shot. The selection of which of these to be used will depend on the design and material from which the component is made.
Also the degree of peening or intensity required from the process.

Glass-bead peening is widely used to produce low intensities and on non-ferrous components. Particle sizes are small and shape excellent.

To achieve higher intensities, it is necessary to utilise the size and mass of cast-or-conditioned cut-wire steel shot. These ferrous products will, of course, contaminate the surfaces of non-ferrous or stainless steel components. If contamination is undesirable, and where use of these medias is necessary to achieve peening intensity, light over-blasting with glass beads or other non-ferrous abrasive media can be used to remove the contamination. Chemical cleaning or use of stainless steel shot may also be appropriate in certain industries.

Design constraints may also influence type of media to be used. The larger the particle size and consequently its mass, the greater the depth and extent of compressive stress or intensity created. It is important however that all the component surfaces are treated equally. If the component includes fillets or threads etc, or if the shot must pass through gaps or holes to peen inside surfaces, the particle size selected must be appropriate. A general rule is that shot diameter should not exceed one-third of the minimum radii or gap through which the particles must pass. Such design restrictions on maximum particle size may require use of steel shot rather than glass beads to achieve the specified intensity.

SPECIFICATION OF PEENING SHOT

Only the specifications and requirements of cast-and cut-wire steel shot will be examined. Both products require different properties for peening use to those specified and necessary for normal abrasive cleaning. These differences will be considered through comparison of the requirement contained within commonly used specifications for each process and their justification.

It is unfortunate that the differences between peening shots and commercial abrasives are still not always recognised. This is believed to be partly due to the complete absence of appropriate specifications for certain peening processes and the short-comings of those abrasive and peening specifications which are available. Many instances still exist where commercial abrasive quality shot is incorrectly used in peening applications to the detriment of the process. It is equally true that people profess to carry out shot peening or offer such services in plant or under controlled conditions such that all they in fact achieve is to shot-blast the components. In both cases the reputation of the process and integrity of the components produced are adversely affected.

In true shot peening there are two distinct applications of the process. The first involves use of an improved or up-graded version of abrasive type shot possessing more closely defined or differing tolerances on properties. This type of media is used in repetition, high volume type applications such as spring and gear manufacture. The requirements of both media and process are to provide consistent reproducible increases in component performance levels. Control of process and quality of output is not possible if equipment, or media
are not maintained within tight limits. Unfortunately whilst equipment has been developed to satisfy these requirements there are no recognised specifications appropriate for the shot used. This is often measured against commercial abrasive shot standards or requires the development of domestic specifications particular to users' own requirements. This leads to problems both in consistency of requirements and manufacturers' ability to exactly meet these various requirements with their products.

The second class of applications generally involve high performance or critical type components such as those found in the aerospace industry. Here the consequences of variable process control can be disastrous. Standards both on media and process are necessarily high and carefully defined. The main specifications for medias and process within these applications are usually based on the MIL-S-13165B (1) specification.

**SIZE**

MIL-S-13165B requirements for cast-shot are much more closely defined particularly in terms of distribution, than either the BS 2451 (2) or SAE J444a (3) standards applying to abrasive qualities. Table 1 illustrates these differences for S230 grade. Similar requirements apply to all other cast shot sizes and to cut-wire shot.

Table 1  S230 Size Requirements

<table>
<thead>
<tr>
<th>MESH APERTURE M.M.</th>
<th>MIL SPEC</th>
<th>B.S.S. 2451</th>
<th>S.A.E. J.444</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.40</td>
<td>S230</td>
<td>S240</td>
<td>S230</td>
</tr>
<tr>
<td>1.18</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>1.00</td>
<td>2% Max</td>
<td>10% Max</td>
<td>10% Max</td>
</tr>
<tr>
<td>0.850</td>
<td>50% Max</td>
<td>75% Min</td>
<td>85% Min</td>
</tr>
<tr>
<td>0.710</td>
<td>90% Min</td>
<td>8% Max</td>
<td>97% Min</td>
</tr>
<tr>
<td>0.600</td>
<td>15% Max</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td>0.500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.400</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This tight control over both size limits and distribution ensures consistent particle size and shape within the process. Peening effect and process control can therefore be more consistently maintained. It must be recognised however that there is little point in paying for such accuracy of size in original condition material if equipment and process do not maintain these standards during use. MIL-S-13165B includes a requirement for shot in the machine to be maintained in such a condition that only 20% is allowed to fall below the minimum particle size specified for the grade. Obviously this means either removal from the machine for re-grading or inclusion of some form of grading equipment for continuous...
removal of undersize particles. In the case of both cast-and cut-wire shot MIL-S-13165B requires the media to be sampled and tested for conformity at least once during every 8 hours of continuous operation and at the beginning and end of each period of operation.

MIL-S-13165B also requires shot to conform to MIL-S-851C (4) requirements. This contains particle size limits although these are less closely defined than those within MIL-S-13165B itself.

Within the series of specifications drawn up by DIN to cover all abrasive media there is a part covering cut-wire (5). They have now produced DIN 8001, a specific standard applicable to wire for use in peening processes (6). This contains size tolerances for the wire both in pre- and post-conditioned or rounded form.

SHAPE

MIL-S-13165B defines both acceptable and unacceptable cast-shot shape and limits the level to which certain unacceptable shapes may be permissible, (Fig 1). The number of deformed particles acceptable varies according to the grade size being considered.

Acceptable Shapes

Unacceptable Shapes, Limited to Table 1

Unacceptable Shapes

Fig 1  MIL-S-13165B Shot Shape

Standard abrasive requirements for cast-shot shape are not generally very well defined and require subjective assessment. Fig 2 compares typical commercial abrasive shape with a MIL standard product.

Normal cut-wire standards such as DIN 8201 Part 4 only consider sharp edged form. SAE J44 (7) states edges may be pre-rounded for special applications and MIL-S-851C requires material to be pre-used or conditioned to form "ball shaped shot". MIL-S-13165B requires cut-wire to be conditioned "to eliminate sharp edges".

The most recent and best specification for cut-wire shot suitable for peening use is DIN 8001. This contains illustrations of various particle shapes both for original and conditioned state material. In the conditioned or "shot" form it is interesting to note the shapes considered unacceptable (Fig 3). The effects of sharp edged particles as in Fig 3a are identical to those of non-round cast shot and are commented upon below. The reason for non-acceptability of Fig 3b is less readily apparent. Prior to issue of DIN 8001 the generally held view
was that "conditioned" cut-wire shot meant spherical particles similar in shape to cast-shot and as illustrated by Fig 3b. Unfortunately to attain such a high degree of rounding involves subjecting the particles to a considerable amount of working. Consequently stresses are built up within the material to such a level that its service life before breaking down is significantly shortened. DIN 8001 clearly believes it is desirable to limit pre-working to the minimum necessary to achieve a suitable shape for peening and not risk premature failure with consequent adverse affects on shape of media in the peening system.

Fig 2 Typical Cast Shot Shapes

Fig 3 Unacceptable Cut Wire Shot Form

The attention given to particle shape for both cast-and cut-wire shot in all peening standards reflects its significance within the process. This is understandable when one considers that the purpose of shot peening is to create compressive stresses in surface layers of components to counteract the surface tensions resulting from cyclic or similar stresses. The presence of sharp-edged or broken particles can create a notch effect or stress concentration which may lead to premature component failure. Under otherwise constant conditions they will also result in varying levels of particle penetration and variation in the uniformity of compressive stress depth.

The importance of correct particle shape and consistency is
emphasised within MIL-S-13165B specification through its requirement for media to be sampled at similar frequencies as those for checking of size. This to ensure that shape is maintained in its original state. The equipment itself, when used for cast-or cut-wire shot peening should "include a separator for continuous removal of broken or defective shot during peening."

HARDNESS

As stated earlier, commercial cast-steel shot is normally offered to a single hardness range. This, in the case of SAE J827 (8) is 40-50 HRC. The variations in hardness range of manufacturers own standards within this range is commented upon elsewhere. MIL-S-13165B does not include any hardness requirement but refers to MIL-S-851C which requires 42-52 HRC. This is not always appropriate for the hardness of component being peened and has led to a proliferation of varying hardnesses specified by different users to suit their own requirements. Table 2 includes examples of those requested and shows standard ranges offered against these by one company.

Table 2 Peening Shot Hardnesses Requested

<table>
<thead>
<tr>
<th>R.C.</th>
<th>440 - 600 HV (45 - 55 HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 - 50</td>
<td></td>
</tr>
<tr>
<td>45 - 55</td>
<td></td>
</tr>
<tr>
<td>50 - 60</td>
<td></td>
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<tr>
<td>50 - 55</td>
<td></td>
</tr>
<tr>
<td>50 - 58</td>
<td>600 - 700 HV (55 - 60 HRC)</td>
</tr>
<tr>
<td>55 - 58</td>
<td></td>
</tr>
<tr>
<td>55 - 60</td>
<td></td>
</tr>
<tr>
<td>55 - 65</td>
<td>750 - 950 HV (60 - 65 HRC)</td>
</tr>
<tr>
<td>60 - 65</td>
<td></td>
</tr>
</tbody>
</table>

In the case of cut-wire shot SAE J441 and MIL S851C hardness requirements are identical. These vary with particle size over the range 36-48 HRC. MIL-S-13165B does not specify hardness as it only considers use of stainless steel shot to a specific composition. DIN 8201 Part 4 provides for 5 ranges of cut-wire hardness for commercial blasting use in sharp-edged form. DIN 8001 covering cut-wire shot for peening is based on use of normal drawn steel wire and specifies hardness as 570-630 HV for cylindrical wire (54-57 HRC) and 610-670 HV for conditioned or rounded wire (56-59 HRC). This is significantly higher than any of the other cut-wire standards and indeed those specified for normal commercial cast-shot. It reflects an awareness of the need for harder shot to suit components being peened.

It should be remembered that the Almen test strips used to measure peening intensity and control processes are themselves produced to a hardness range of 44-50 HRC. This is higher than the lower limits quoted in most cast-or wire-shot specifications.
Use of peening media of high hardness than components being peened is accepted as being necessary to achieve consistent results and creation of suitable depths of compressive stress layers. A direct relationship does exist however between hardness and life or durability of both cast-and cut-wire shot (Fig 4). To over-specify hardness leads to increased cost of replacing media. Greater attention will also be required to maintenance of media condition during processing as the rate at which broken particles are generated will increase.

![Steel Shot Life Comparison](image)

**Fig 4 Steel Shot Life Comparison**

**CONCLUSION**

Clear differences exist between media requirements for commercial abrasive blast-cleaning and peening processes. The need for these differing or more tightly controlled tolerances are justified when one considers the process being applied and the effects produced on components being treated. The process is critical in nature and abuse of technique or standards of control can result in component properties being adversely affected rather than increased.

A need exists for media and process standards designed to satisfy the demands of peening processes. At the present time those standards which are available do not cater for the requirements of high volume type applications. They concentrate only on the needs of critical type components used in highly demanding environments such as aerospace and similar industries. Even in these cases the specifications are not comprehensive as they rely on reference to poor abrasive product standards for definition of basic requirements. In the case of shape only DIN 8001 satisfactorily defines cut-wire shot form and this standard has not been widely accepted. It also limits itself to only one hardness of wire. In the MIL-S-13165B specification, hardness is ignored other than by
reference to MIL-S-851C. This, together with equivalent cast-steel shot abrasive standards, only consider a single relatively low hardness of product which will not satisfy all requirements. MIL-S-13165B ignores all but a stainless steel type of cut-wire shot.

The existing specifications are out-dated and require review and standardisation to reflect the needs of peening industry today.

REFERENCES

1. MIL-S-13165B 1979 Shot Peening of Metal Parts.