GENERAL ASPECTS OF SHOT PEENING
CRITERIA OF PARAMETERS SELECTION

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ABSTRACT

Major groups of parameters affecting the shot peening process and quality of peened parts have been determined in the paper. These are as follows:
- shot peening equipment
- types and size of shot
- peening intensity
- surface coverage

Methods and frequency of inspection for the shot peening process as a function of type of machine elements to be peened have also been given.

KEY WORDS

Shot peening data, shot peening equipment, types and sizes of shot, peening intensity, surface coverage, destructive method of shot peening control, non-destructive method of shot peening control.

INTRODUCTION

Shot peening is one of the methods of cold working which is suitable for machine elements made of metals or plastics. The major applications of shot peening is related to improvement of fatigue life of parts. According to obtained results /Horowitz, 1973/, subject to a method of peening, the improvement can ranges from 15% to 200%. Such a great increase in fatigue life is possible due to coupling heat treatment to cold working represented by shot peening. Shot particles for peening should be made of cast iron /ball shot/ or cut steel wire /cylindrical shot/. Out of shots used for work hardening purposes are these made of cast iron, chilled iron shot, cast steel, glass, spring wire. The equipment used in shot peening can be mechanical, pneumatic combined with mechanical or pneumatic. In the mechanical equipment a revolving bladed wheel provide shot with kinetic energy while in case of a pneumatic equipment shot is accelerated by a continuous stream of
compressed air. The choice of a suitable equipment depends first of all on:
- sizes and shape of parts
- rate of production

SELECTION OF SHOT PEENING PARAMETERS

General process characteristic

The quality and effectiveness of peening depends on the following parameters:
- types and sizes of shot
- shot peening intensity
- surface coverage

For the purpose of obtaining the optimum results of shot peening above mentioned parameters may be governed by:
- number of rotors /mechanical propeller/
- number of nozzles and their diameters /pneumatic propeller/
- velocity and character of motion of parts or nozzles
- distance between peened parts and shot propelling wheels or nozzles
- exposure time

Type and Sizes of Shot

Selection of shot for work hardening depends largely on:
- required thickness of work hardened layer
- required roughness number

General requirements as to steel shot, cut steel wire shot and glass beads used in work hardening are given in Tables 1 and 2. Table 1 lists ranges of shot with the recommended groups of parts. The recommended sizes of cast shot and cut steel wire shot for the application to different parts are given in Table 2. Cut steel wire shot has to be conditioned to eliminate sharp edges.

TABLE 1 General Recommendations for Types and Sizes of Shot Used in Work Hardening

<table>
<thead>
<tr>
<th>Types of parts</th>
<th>Globular cast steel shot /diam. in mm/</th>
<th>Cut steel wire shot /diam. in mm/</th>
<th>Glass bead /diam. in μm/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring leaves</td>
<td>0.30 - 0.75</td>
<td>0.40 - 0.60</td>
<td>175 - 300</td>
</tr>
<tr>
<td>Spiral springs</td>
<td>0.30 - 1.00</td>
<td>0.60 - 0.90</td>
<td>50 - 200</td>
</tr>
<tr>
<td>Gear wheels</td>
<td>0.30 - 1.00</td>
<td>0.40 - 0.90</td>
<td>50 - 200</td>
</tr>
<tr>
<td>Shafts</td>
<td>0.30 - 1.00</td>
<td>0.40 - 0.90</td>
<td>50 - 100</td>
</tr>
</tbody>
</table>
TABLE 2 Recommendations for Materials of Cut Wire Steel Shot and Globular Cast Steel Shot Used in Work Hardening

<table>
<thead>
<tr>
<th>Types of parts</th>
<th>Cut wire steel shot</th>
<th>Globular cast steel shot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Designation and sizes of shot</td>
<td>Tensile strength for wire</td>
</tr>
<tr>
<td></td>
<td>SLD-G (^1) (/\text{mm/}))</td>
<td>(\text{CW}^{2}/ \text{MPa/10^{-3} in/})</td>
</tr>
<tr>
<td>Small parts</td>
<td>0.4; 0.6</td>
<td>20; 23</td>
</tr>
<tr>
<td>Large parts</td>
<td>0.7; 0.8</td>
<td>28; 32</td>
</tr>
<tr>
<td></td>
<td>0.9; 1.2</td>
<td>35; 47</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>54</td>
</tr>
<tr>
<td>Spring leaves</td>
<td>0.7; 0.8</td>
<td>28; 32</td>
</tr>
<tr>
<td>/ heavy/</td>
<td>1.2; 1.4</td>
<td>47; 54</td>
</tr>
<tr>
<td>Coil springs</td>
<td>0.8; 0.9</td>
<td>32; 35</td>
</tr>
<tr>
<td>Spiral springs</td>
<td>0.4</td>
<td>20</td>
</tr>
<tr>
<td>Torsional shafts</td>
<td>0.4</td>
<td>20</td>
</tr>
<tr>
<td>Shafts / accor-</td>
<td>0.4; 0.6</td>
<td>20; 23</td>
</tr>
<tr>
<td>ding to size/</td>
<td>0.9</td>
<td>35</td>
</tr>
<tr>
<td>Gear-wheels</td>
<td>0.6; 0.9</td>
<td>23; 25</td>
</tr>
</tbody>
</table>

\(^1\) Designation in accordance with DIN 8201 part 2 /1977/ and part 4 §1975/ 
\(^2\) " " " " SAE J441 /1969/ and J827 /1969/

Delivered shot should in accordance with the obligatory standards be always given a sieve analysis.
Cast steel shot should conform to SAE J827 /1969/ and cut steel wire shot to SAE J441 /1969/.

Determination of Shot Peening Intensity

Shot peening intensity is determined by a measurement of one side peened test strip deflection. The strip is commonly referred to as the Alman test strip. In accordance with SAE J442 /1968/ the test strips should be made of material given in Table 3. The set of strips includes N, A and C strips. These strips are applied to low, middle and high peening intensity respectively. When middle intensity is involved, test strip A is preferably used. Deflection of the strip should range between 0.15 - 0.6 mm. For deflections lesser than 0.15 mm test strip N is recommended, for greater than 0.60- test strip C. To conform to recommendation /Kugelstrahlen-Shot Peening NO5154, 1977/ peening intensity should be determined with regard to cross section of the part to be peened.
TABLE 3 Materials for the Almen Test Strips

<table>
<thead>
<tr>
<th>Type of material</th>
<th>Components content /%/</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C Mn Si P S Ni Cr max</td>
<td></td>
</tr>
<tr>
<td>Cold rolled</td>
<td>0.65 0.6 - 0.040 0.050 - -</td>
<td>Recommended standard: SAE J442, 1968</td>
</tr>
<tr>
<td>spring steel</td>
<td>0.75 0.9 - 0.045 0.045 - -</td>
<td></td>
</tr>
<tr>
<td>according to SAE1070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold rolled</td>
<td>0.75 0.7 0.4 0.045 0.045 - -</td>
<td>Recommended standard: &quot;Steyer-Daimler-Puch&quot; N 05154</td>
</tr>
<tr>
<td>spring steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>according to DIN 17222 C 75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>0.62 0.5 0.17 0.040 0.040 0.25 0.35</td>
<td></td>
</tr>
<tr>
<td>spring steel</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>according to PN-74/H-84032 65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>spring steel</td>
<td>0.80 0.50 0.17</td>
<td></td>
</tr>
<tr>
<td>according to PN-74/H-84032 75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or 75 select a to BN-76/0631-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring steel</td>
<td>0.60 0.90 0.15 0.040 0.040 0.30 0.30</td>
<td></td>
</tr>
<tr>
<td>according to PN-74/H-84032 65G</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 indicates approximate recommendations for the peening intensity according to standard. The Almen strips are fastened to the test strip holder, and strips deflections measurements are made by a special dial gauge. For the purpose of determining optimum peening intensity test strips deflection exposure time relationship must be established, by way of experiment, a first. The curve in given in Fig. 1. This is a resultant curve out of three obtained for test strips of the same type. The value of strip deflection in point A indicates a desired peening intensity. Sphere above point A corresponds to little gain in the strip deflection with much increase in exposure time. Having regard to economy, it is undesirable
to shot peen within long time of exposure /high costs of production/. On the other hand short time of exposure results in poor quality of the shot peening process. The time of exposure should be ordinarily determined so that strip deflection fall close to point A.

TABLE 4 Recommended Peening Intensity Regarding Thickness of Part to be Peened

<table>
<thead>
<tr>
<th>Thickness of diameter of peened part /mm/</th>
<th>Test strip deflection /mm/</th>
<th>Type of the Almen strip</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.30</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>0.45</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>0.55</td>
<td>A</td>
</tr>
<tr>
<td>16</td>
<td>0.18</td>
<td>C</td>
</tr>
<tr>
<td>19</td>
<td>0.20</td>
<td>C</td>
</tr>
<tr>
<td>22</td>
<td>0.25</td>
<td>C</td>
</tr>
</tbody>
</table>

Fig. 1. Shot peening intensity curve

**Surface Coverage**

This is surface coverage which is tightly related to effect of shot peening on quality of the process. Surface coverage is a measure of how completely a surface has been hit by flux of impinging shot particles. Without adequate coverage, the improvement in fatigue characteristics normally produced by shot peening will not be obtained. As stated in SAE J443 /1968/, there is a definite and quantitative
relationship between coverage and exposure time, which may be expressed as follows:

\[ \text{C} = 1 - \frac{1}{1 - \text{C}_1^n} \]

where \( \text{C} \) = % coverage after \( n \) cycles
\( \text{C}_1 \) = % " " 1 cycle
\( n \) = number of cycles.

This relationship indicates that coverage approaches 100% is a limit and can be obtained after extremely long time. Because accurate measurement can be made up to 98% coverage, this value is arbitrarily chosen to represent full coverage, in accordance with /Horowitz 1976/. The importance of the formula /1/ is explained in Fig. 2: Fig. 3, shows appearance of 55% coverage surface /fig. 3a/ and 90% coverage /Fig. 3b/. These pictures correspond to points 1 and 2 in Fig. 2.

\[\begin{array}{cccccccc}
\text{Time /min/} \\
2 & 4 & 6 & 8 & 10 & 12 & 14 & 16 \\
\hline
0 & 20 & 40 & 60 & 80 & \\
\end{array}\]

\[\begin{array}{cccccccc}
\text{Coverage /%/} \\
0 & 20 & 40 & 60 & 80 & 100 \\
\hline
0 & 20 & 40 & 60 & 80 & \\
\end{array}\]

![Graph](image)

**Fig. 2.** Surface coverage as a function of time: 1 - exposure time corresponding to 55% coverage /determined by way of microscopy/, 2 - exposure time corresponding to 90% coverage /determined by way of microscopy/

*SAE J443, 1968* provides procedures for determining and controlling surface coverage. Visual method for measuring coverage consists in examining the surface at a magnification of 50 diameters.

**METHODS FOR THE CONTROL OF SHOT PEENING PARAMETERS**

The resultant effect of: type and size of shot, air pressure or rotational speed of a bladed wheel, nozzle diameter, nozzle - part distance, angle of impingement and exposure time on quality of peening depends on the control of each of these variables. There are some methods for controlling above mentioned parameters:  
- direct observation during shot peening
Fig. 3. Appearance of a peened surface: a - 55% coverage, b - 90% coverage

- measurement of deflection of Almen test strips and measurement of coverage
- distribution of hardness analysis
- metallographic analysis
- results of fatigue testing comparisons.

Table 5 provides procedure for current control of shot and shot peening parameters according to standard /BN-780/7002,1/.

| TABLE 5  Specification for Control of Shot Composition and Shot Peening Parameters |
|---------------------------------|-----------------|-----------------|-------------------|
| Parameter                      | Testing time                     |
| /Desired properties/           | Peened parts | Almen test strips | Shot composition |
| Peening intensity             | -          | After 60 h time peening | -               |
| Coverage                       | After 20 h time peening | a, b.          | -                |
| Sieve analysis                | For shot | - | - | Just after delivery and after initial elimination of sharp edges for cut steel wire shot |
| For shot composition          | -          | - | After 60 h time peening | -               |
| Fatigue test                  | For new production | - | - |
CONCLUSIONS

The shot peening process requires an accurate selection of shot peening parameters. A correct selection of shot peening parameters should be based on non-destructive testing of surface layer, having regard to an adequate criterion of mechanical properties, e.g. fatigue life. In practical conditions it is enough to meet peening intensity demands determined by measuring deflection of the Almen test strips.

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