Project Background

Background: Shot peening strengthens a material’s surface by inducing a compressive stress. To create a predictable uniform stress, the size and shape of the shot is expected to be uniform; however, there is typically some variance from this ideal. Currently the ASTM and SAE specifications, dating from 1942, require manufacturers to classify the shot size using mesh sieves. This project considers the use of modern image analysis for updating size and shape specification. Image analysis provides in-depth analyses of size and shape characteristics and further elucidates the change in these characteristics as a function of peening process variables.

Purpose: This project’s goals can be broken down into two sections: 1) characterize standard AMASTEEL S-shot peening media based on size and roundness using image analysis and 2) analyze breakage data to create a simple model for predicting likelihood of breakage. The project aims to recommend quantifiable specifications for size and shape and provide replicable models for prediction breakage under peening process conditions. This project hopes to affirm colloquial industry knowledge and provide new analysis on the hidden life of a shot.

Results and Discussion

Characterization of size and shape

Figure 2: Frequency and cumulative size distributions based on shot volume, AMASTEEL, S230, S320 H and S550 (obtained from Ervin Industries, Adrian MI). The plots show the geometric distribution of shot size. S320H has the widest size distribution while S550 has the narrowest.

Per the graphs above and sample table to the left, log-normal (Gaussian) and Weibull (stretched-exponential) functions are used to describe size and shape features respectively. Compared to sieving, image analysis provides more detail on the distribution of size and enables quantified analysis of shape.

Sample Table

<table>
<thead>
<tr>
<th>Sample</th>
<th>Size (mm/mc)</th>
<th>Roundness (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S230</td>
<td>Ø142 - Ø452</td>
<td>0.96 - 0.99</td>
</tr>
<tr>
<td>S230H</td>
<td>Ø80 - Ø500</td>
<td>0.95 - 0.97</td>
</tr>
<tr>
<td>S550</td>
<td>Ø83 - Ø505</td>
<td>0.94 - 0.96</td>
</tr>
</tbody>
</table>

Table listing size and roundness of S230, S230 H and S550 shot. SAE specification for size has been added for comparison. Currently, there is no SAE specification for roundness; figures in parentheses (%) are suggested.

Experimental Procedure

Shot Characterization

Characterization was performed using image analysis tools. The data uses 2D projections of back-lit shot particles falling from a vibratory feeder. A Standard Operating Procedure was created for characterizing shot using the JM Canty SolidSizer. The raw data for individual particles include the area (A) and perimeter (P). Area and Perimeter were used to calculate Roundness ($r = 4\pi A/P^2$) and Equivalent Circumferential Diameter ($D_{eq} = 2\sqrt{A\pi}$).

Figure 1: SolidSizer schematic. A curtain of particles falls from a vibratory chute. Back-ill 2D projections are captured by a high-speed camera over a sequence of images. Typical data sets have an access of 10,000 particle images.

Breakage Characterization

Three shot types @ S550 ii) S230 and iii) S230 Hard were exposed in increments up to 1500 cycles at either 7000 rpm or 8000 rpm using an Ervin tester. The shot was characterized using the shot characterization Standard Operating Procedure. With the data, a model for survival threshold was created by least-squares fitting to a hypothetical equation: Predicted Survival = bias – In(KE + N^a).

where KE is the intercept. KE is the kinetic energy of the shot, k is a scaling factor of the importance of the KE. N is the number of impacts and n is the scaling factor of the importance of N.

Recommendations

Methodology, JM Canty Image Analysis:

- Analysis software to enable front-lit color analysis for tracer studies of shot-peening interactions;
- Explore in-line analysis for process monitoring and control of high-value-added peening operations.

SAE Specification (work w/ SAE committee):

- Deploy Standard Operating Procedure for Image Analysis.
- Need agreement of updated size specifications.
- Discussion and alignment on shape specifications.

Research:

- Further develop the breakage model using statistical measures (building on this study) combined with microstructural approach (e.g., toughness, crack growth).

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Shot peening is the process of strengthening a material by inducing a compressive stress across the surface. The size and shape of the shot is expected to be uniform; however, there is typically some variance from this ideal. The purpose of this project is to better characterize shot size and shape characteristics and further elucidate the change in these characteristics as a function of peening process variables. This poster, the team proposes log-normal and Weibull functions to fit size distributions and rounded as a new specified shape for size distributions. As well as recommendations for distribution models, the team proposes a breakage prediction model for peened shot using kinetic energy and number of impacts. The intended usage for the project is to affirm colloquial industry knowledge and provide new analysis on the shot peening life cycle.