Specification Development of Shot Media Using Image Analysis

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Dynamic image analysis (DIA) offers benefits to the characterization of steel shot media particles previously unattainable through traditional sieving. Utilizing a JM Canty SolidSizer, size and shape characterization of shot media was conducted in accordance with existing industry specifications. Upon analysis of particle distributions, guidance for an improved specification with the inclusion of size characterization control targets and quantifiable shape analysis was developed.

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Project Background

Scope: Industrial practices require a robust shot characterization method addressing both size and shape of media to enhance the results of shot peening. Current practice uses sieving, characterizing particles by size though a tiered tower of decreasing diameter mesh sieves, with minimal consideration to particle shape. Shifting to **dynamic image analysis** provides a quantifiable data collection source via cross-section capture for realistic and manageable industry integration. A defined threshold value on a black/white scale differentiates particle versus background, producing data that can be translated into cumulative distributions representative of size of shape of each particle in a sample.

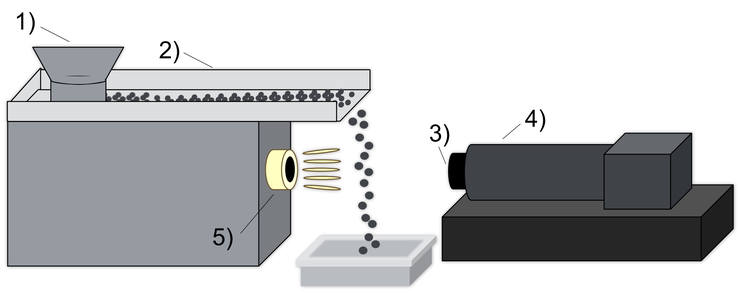
Media Type: The enhanced specification is framed around six steel shot samples of two metal shot manufacturing types. Cast shot is produced by atomizing molten steel during freefall, producing highly spherical shot. Cut-wire shot is manufactured by slicing particles at lengths equal to the diameter from steel wire and machined to a spherical shape. Of these two types, three sizes of each were used to align with project scope. Included are cast shot sizes **S110, S230**, and **S330**, and cut-wire shot sizes **CW14**, **CW20**, and **CW32**.

Experimental Procedure

Benefits of using JM Canty SolidSizer:
- Dynamic imaging of particles in freefall
- Ability to easily capture 10,000+ particles in a single test
- Ease of parameter adjustment

Important Components of SolidSizer:

1. Hopper
2. Dry system vibratory feeder
3. Camera
4. Zoom and Focus Control
5. Back-lit LED

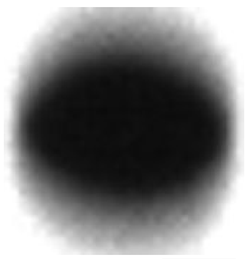


Parameters Applied to all Shot Media Samples:
- Threshold value of 173
- Gain of 21 dB
- Light Intensity of 250 mA (constant current, DC)

Parameters Specific to Shot Size Categories

	Approx. Diameter [mm]	Zoom	Scale [µm/pix]	Focus	Aperture	Exposure Time [µs]
Cast S110	0.400	1.28	7.15	315	15	50
CW 14	0.450	1.28	7.15	315	15	50
Cast S230	0.725	0.97	10.3	530	10	120
CW 20	0.638	0.97	10.3	530	10	120
Cast S330	1.015	0.97	10.3	530	10	120
CW 32	0.945	0.97	10.3	530	10	120

Need for Optimized Parameters



Unoptimized Cast S330 Shot Particle

- Out-of-plane image
- Undefined edges
- Unreliable shape analysis

300 µm

Optimized Cast S330 Shot Particle

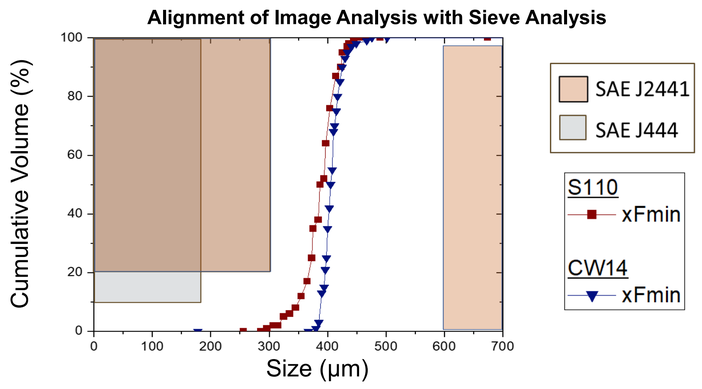
- In-plane image
- Well-defined edges
- Reliable size and shape analysis

300 µm

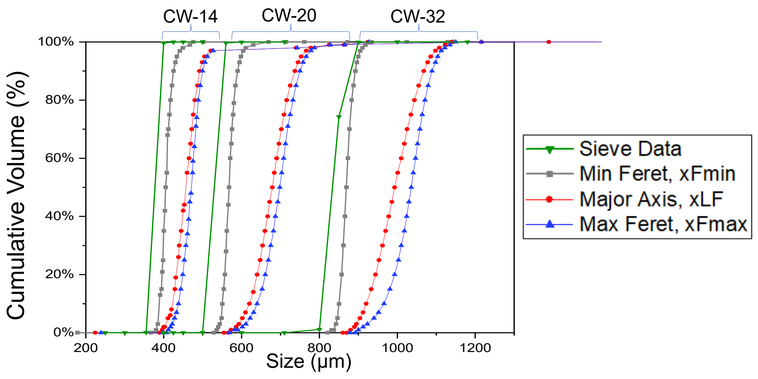
Results & Discussion

Current State Characterization

J2441 Specifications	CW-14	S110	CW-20	S230	CW-32	S330
0.5% (by weight) retained on US Sieve Size mm (in)	0.600 (0.0234)	0.600 (0.0234)	0.850 (0.0331)	1.00 (0.0394)	1.18 (0.0469)	1.40 (0.0555)
20% (by weight) passing US Sieve Size mm (in)	0.300 (0.0177)	0.300 (0.0177)	0.425 (0.0165)	0.600 (0.0234)	0.710 (0.0278)	0.850 (0.0331)

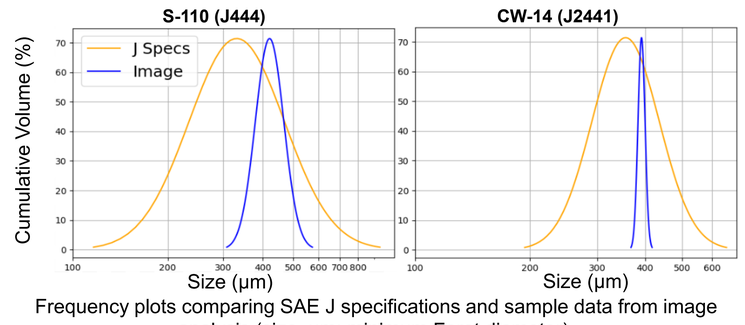


- **Current Specifications:** SAE J2441 & SAE J444
  - 300 µm diameter difference between S-110 & CW-14, per J2441
  - ±14 µm sieve discrepancy, per ASTM-11 standards
- Provides the opportunity to tighten tolerances of sieve size analysis
- Dynamic Image Analysis has observed noteworthy size differences between CW-14 & S-110, regardless of identical SAE J standards
- Both shot media are well within the limits of the SAE J2441 and J444 specifications which agrees that minimum **Feret diameter** gives a consistent size evaluation than the current sieve specifications.



- Cumulative volume provides a correlation to sieving size analysis
- **Minimum Feret diameter**
  - Observed as the best comparison between sieving and DIA

Dynamic Image Analysis Proposed Specification



Frequency plots comparing SAE J specifications and sample data from image analysis (size, µm: minimum Feret diameter).

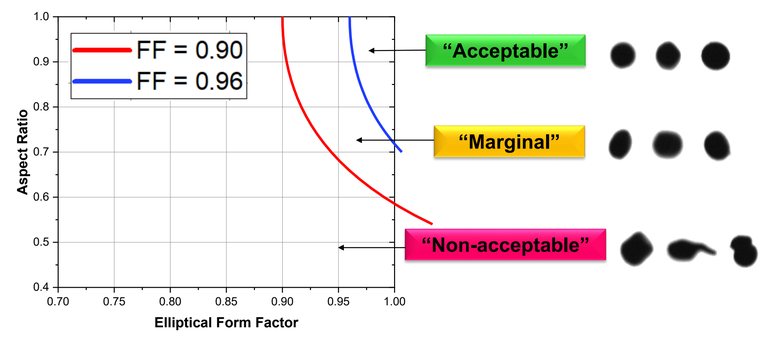
Size Descriptor: Minimum Feret Diameter						
Type of Shot	Cast Shot (um)			Cut Wire Shot (um)		
	S-110	S-230	S-330	CW-14	CW-20	CW-32
95% passing	591	910	1190	496	868	1226
90% passing	516	853	1131	463	823	1156
50% passing	333	696	942	356	683	963
25% passing	258	617	856	310	613	875

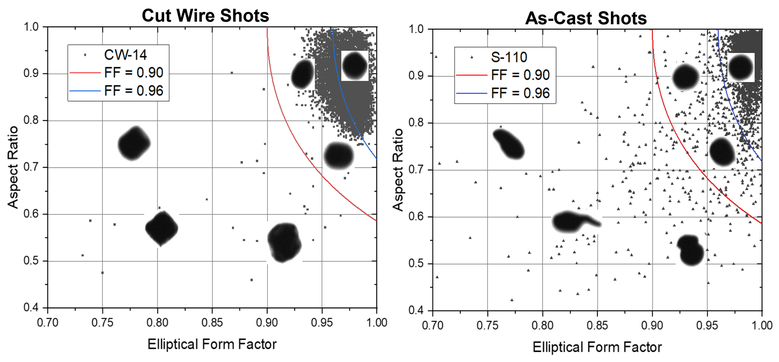
- **Quantiles** of DIA size analysis used to characterize particle size distribution within current SAE J-specification

Goal:
- Create a J-specification that utilizes DIA and it equivalent to current standards

Results & Discussion

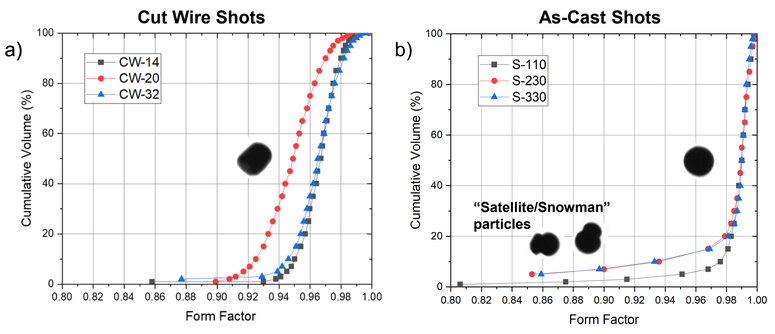
Dynamic Image Analysis Shape Characterization





- **Form factor** (FF) is numerical to both Elliptical Form Factor and Aspect Ratio
  - Both are used to define the shape irregularities of cut-wire and as-cast shots

Acceptable, Marginal, and Non-Acceptable
- Quantitatively define shape quality of shot



ISO-defined Form Factor to be used as quantitative measure of shape
- Relates to circumference of area normalized to a circle
- Requires an observed perimeter of each particle

- Cut-Wire has a broader distribution of FF than Cast shot
  - Q = 50%, 0.97 FF for cut-wire
    - Manufacturing process: Cutting the cold drawn wire into lengths equal to the wire diameter - elongated shot particles
  - Q = 50%, 0.99 FF for cast
    - Manufacturing process: Atomized molten steel due to surface tension during free fall – high spherical shot particles.
- Cast shot tends to have a tailing effect in shape analysis
  - Likely due to occasional 'satellite' particles

Conclusion and Recommendations

Conclusions

Developed expanded SAE J444 specification to incorporate image analysis as an alternative characterization method
- Parameter optimization is key for accurate representations of shot
- DIA follows sieve determined size distributions using xFmin
- First quantitative measure of steel shot shape using Form Factor

Recommendations
- Utilize area equivalent diameter (X_A) as the size descriptor to correlate shot size and peening energy.
- Introduce elliptical form factor (EFF) as the shape descriptor for cut-wire shot to represent cylindrical shape.
- Offer tighter shape definitions for cut-wire shot for increasing conditioning levels .
- Integrate offsite data underway at Toyo Seiko & Electronics, Inc.

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MSE 430 - 440: Materials Processing and Design