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Particle Size Image Analysis of Explosive Formulation & Ingredients

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Abstract

Particle size and shape play an important role in the processing of explosive ingredients and formulations. They affect the flow ability, packing, pressing, and sensitivity of explosive ingredients and formulations. Traditionally particle size analysis for explosive formulations and ingredients has been determined by standard sieving methods (wet and dry). More recently particle size measurements of ingredients have moved to the use of light scattering techniques. These methods of particle size analysis have limitations to characterizing samples. For sieving the primary limitations is poor particle size resolution, which is limited by the standard sieve sizes manufactured. Additionally sieving is labor intensive compared to light scattering and other methods. Limitations for light scattering techniques include poor resolution for very narrow distributions and that rather than a direct measure of the particles it measures the interaction of light with the particles and converts this information to particle size based upon mathematical theory.

Dynamic particle imaging analysis is a technique that can overcome some of the limitations of other particle sizing methodologies. In dynamic particle imaging analysis dispersed particles (wet or dry) pass in front of a bright, pulsed light source. Images of the shadows of the particles are captured with a digital camera. Software then analyzes the size and shape of each particle, and finally calculates the respective distribution curves for both size and shape parameters of the sample.

BAE Systems Ordnance Systems has evaluated the use of a dynamic particle image analyzer to measure the particle size distribution of multiple granulated explosive formulations and ingredients as an alternative method to standard sieve analysis and light scattering techniques. In addition to particle sizing, the shape characteristics of the granulated explosive formulations and ingredients were also measured. A comparison of results, sample preparation, and limitations of these methods of particle size analysis are presented.

Background

Particle image analysis describes the general technique of acquiring an image of a field of view containing particles with a digital camera. This image is then processed via software to segregate particles from the background and to perform image analysis operations on each of those particles resulting in dimensional measurements. The measurements for each particle are then used to generate population statistics of the sample. Particle image analyzers can be divided into two subgroups, static and dynamic, depending upon the acquisition method of the images.

Static image analyzers are the most common form and work by dispersing a sample onto a microscope slide and imaging with a microscope fitted with a digital camera. Once the image is acquired it is processed and analyzed. With static image analyzers only one field of view is captured at a time, to view other portions of the slide the sample stage is moved and the process repeated.

Dynamic image analyzers operate by passing particles in front of the digital camera and optics system and then using high speed flash illumination, synchronized with high shutter speed on the camera to capture images of the particles. This method enables the acquisition of particle data at a much higher rate than in static image analyzers, meaning statistically significant populations can be analyzed in a far shorter time.

With dynamic image analyzers there are multiple ways to pass particles in front of the camera for analysis. Dry free flowing samples may be fed via a vibration table to fall by gravity past the camera, while dry samples prone to agglomeration may be dispersed using an air pressure driven system. Finally samples may also be analyzed in suspension using a liquid flow cell.

The system used within this study is the Camsizer XT manufactured by Retsch. The system is equipped with all three sample dispersion methods described previously, gravity, air driven, and liquid flow cell.

Results and Discussion

Granulated Explosives Formulations

Particle size distribution of granulated explosives formulations were evaluated using the Camsizer XT equipped with the gravity dispersion equipment in comparison to standard sieving method of analysis. For this evaluation samples of a granulated explosive formulation were used for comparison. Two samples were collected and analyzed first by the Camsizer XT, followed by the standard sieve analysis for this granulated explosive formulation. Table 1 shows a comparison of the sieve size results from the two methods, while Figure 1 shows the cumulative distribution graphs for each material.

Table 1. Comparison of Sieve Size Analysis

Sample	#6	#12	#30	#60	#80	PAN
Sample 1- Camsizer	0.0	0.1	95.6	4.20	0.1	0.0
Sample 1 - Sieve	0.0	0.0	93.8	6.10	0.0	0.1
Sample 2 - Camsizer	0.0	0.1	98.4	1.4	0.0	0.1
Sample 2 - Sieve	0.0	0.0	98.5	1.4	0.0	0.1

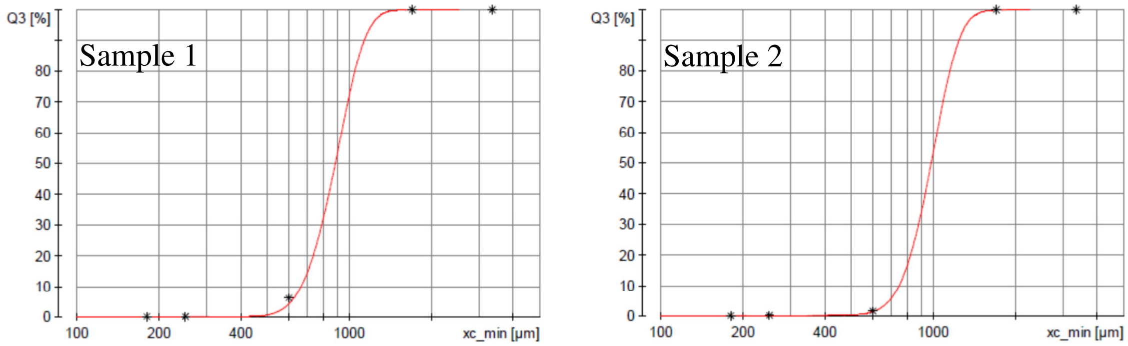

Figure 1. Two Batches of Granulated Explosive Formulation Particle Size Distribution Comparison (Red Curve – Camsizer , Black Stars – Sieve Analysis)

These materials showed good agreement with the sieving data; however the sieve data only evaluated the extremes of the distribution.

A second set of evaluations were performed upon another granulated explosive formulation, however after image analysis was completed, screens were chosen to look at the bulk of the distribution. Table 2 shows a comparison of the sieve size results from the two methods, while Figure 2 shows the cumulative distribution graphs for each material.

Table 2. Comparison of Sieve Size Analysis

Sample	#4	#20	#40	#50	#60	#100	PAN
Sample 1 Camsizer	0.0	3.3	50.3	31.7	8.8	5.7	0.2
Sample 1 Sieve	0.0	1.2	45.5	35.7	9.4	7.9	0.3

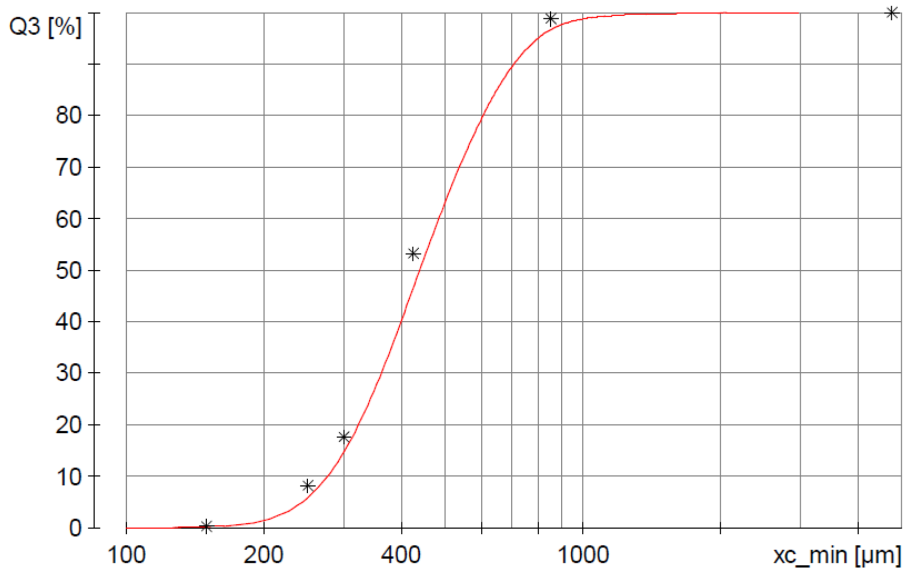

Figure 2. Granulated Explosive Formulation Particle Size Distribution Comparison (Red Curve – Camsizer , Black Stars – Sieve Analysis)

As with the previous materials the extremes matched very well to the sieving data, however slight differences were observed in the data taken from the heart of the distribution.

Explosive Ingredients

Particle size distribution of explosives ingredients were evaluated using the Camsizer XT equipped with the air pressure dispersion equipment in comparison to laser diffraction method of analysis. Four batches of an explosive ingredient were evaluated for both shape and size. For the shape analysis the width/length ratio has been evaluated to look at the amount of rod or needle like materials present in the samples. In Figure 3 graph of the cumulative and frequency distribution of the shape is shown.

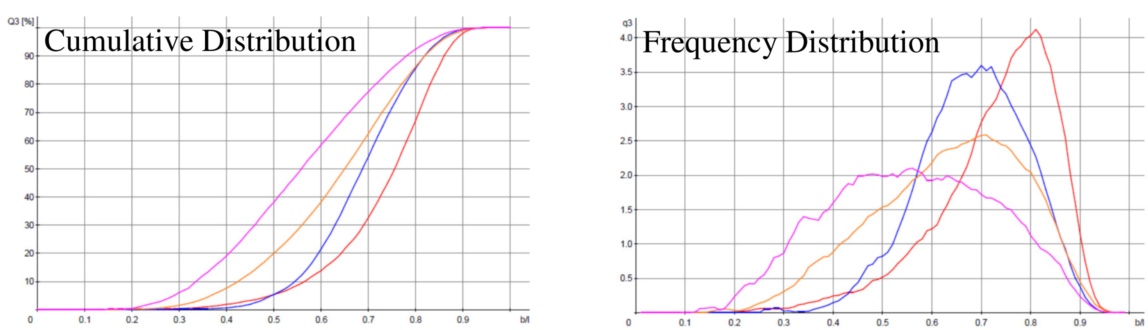

Figure 3. Explosive Ingredient Particle Shape Distribution Comparison (Violet Sample A, Orange Sample B, Blue Sample C, Red Sample D)

These graphs show that there is a difference in particle shape distribution between these four batches. Table 3 shows the mean width/length ratio and the % composition with a width/length ratio less than 0.5 which show the increasing rod like character of the materials.

Table 3. Comparison of Explosive Ingredients Particle Shape

Sample	Mean Width/Length	% Width/Length < 0.5
A	0.558	38.2
B	0.634	20.0
C	0.683	5.4
D	0.730	5.4

Figure 4 shows optical images of each of the four batches which agree with the differences in particle shape as measured by image analysis.

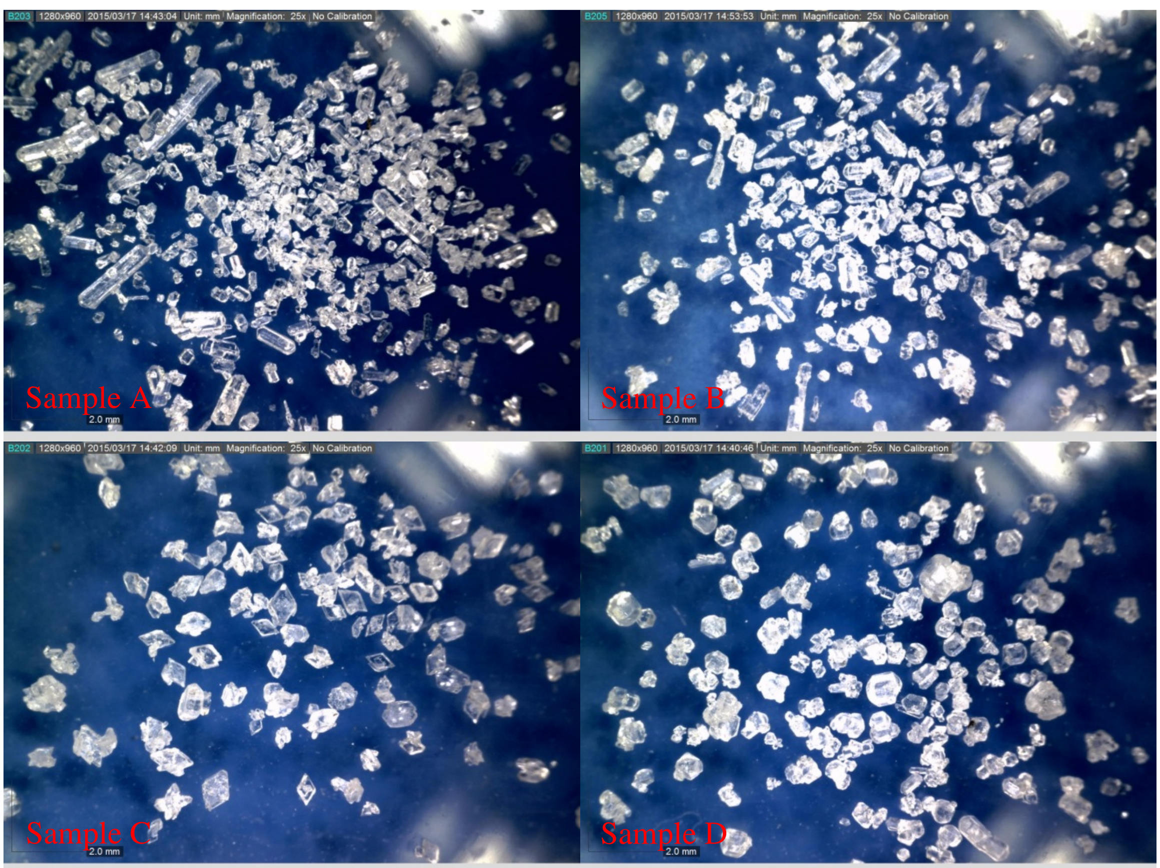

Figure 4. Optical Images of Particle Shape of Explosive Ingredient Batches

Comparison of the particle size of the explosive ingredients batches between laser diffraction and image analysis shows larger differences for materials that are more rod like than for those that are more spherical. Figure 5 shows the cumulative distribution curves for Sample C and Sample A by both laser diffraction and image analysis.

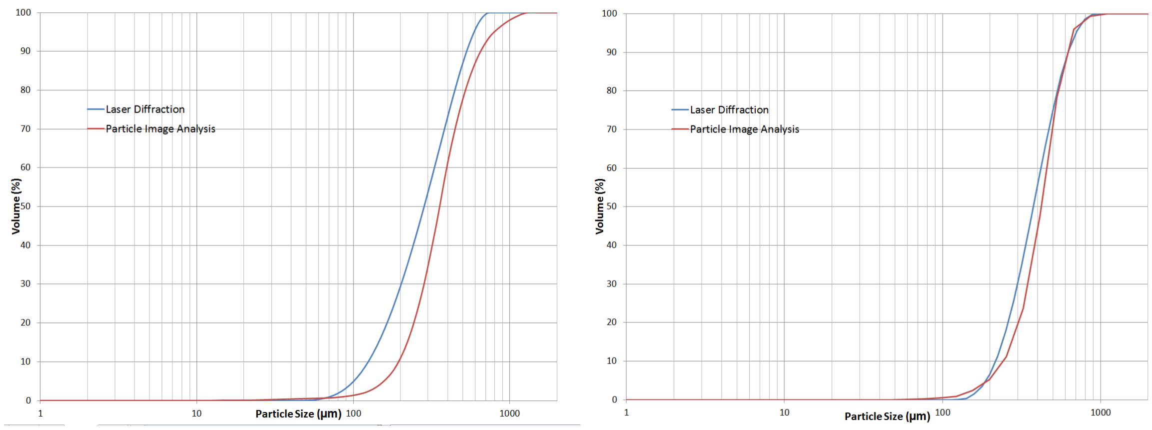

Figure 5. Cumulative distribution graphs of Explosive Ingredients with different Width/Length Ratios by Laser Diffraction and Image Analysis
(A) Ratio < 0.5 – 20% (B) Ratio < 0.5 – 5.4%

This discrepancy in predicted size is caused by the fact that laser diffraction results are based upon a spherical equivalent diameter volume of a particle, which doesn't adequately describe a rod. Figure 6 shows how the conversion of the volume of a rod to the volume of a sphere equates to a diameter between the size of the width and length. As the length of the rod increases the discrepancy in predicted size also increases.

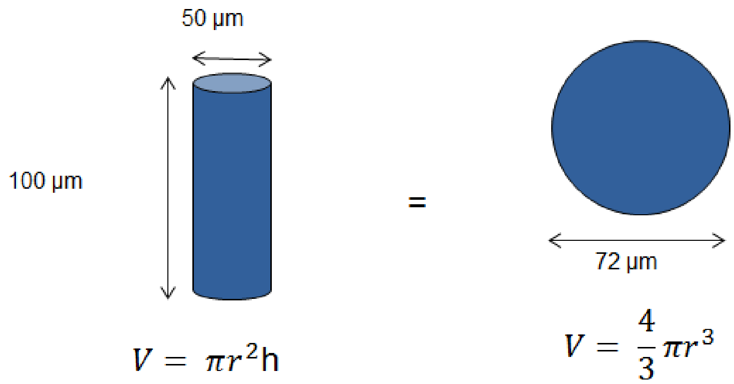

Figure 6. Conversion of Volume of a Rod to Volume Equivalent Sphere Diameter

Conclusions and Future Work

Image analysis has been used to evaluated particle size and shape of explosive formulations and ingredients. Image analysis can cover a range of particles (1µm to 3 mm) that lies within the ranges of both laser diffraction (10 nm to 2 mm) and sieving (40 µm to 125 mm). This range is consistent with the range of sizes for most current production explosive ingredients and formulations. Good correlation was observed between seiving and image analysis for explosive formulations. Likewise images analysis provided results that were similar to laser diffraction. It was shown that particle shape can effect the outcome of particle size based upon laser diffraction and how image analysis can provided a better representation of the particle size for non spherical particles. Image analysis can also provide insight into particle shape distribution, a tool that no other particle sizing method can perform.