

Image Analysis and Computer Microscopy of Shot Particles

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INTRODUCTION

This paper is intended to show how useful quantitative and qualitative information about shot particles can be obtained using only simple equipment and a rudimentary knowledge of image analysis. Primary producers of shot need relatively complex equipment and trained staff to routinely assess quality control parameters using image analysis. Most users of shot, however, cannot afford those luxuries. The recently introduced Intel™ QX3™ computer microscope offers an opportunity for virtually anyone in the peening industry to carry out image analysis on shot particles for an outlay of only about one hundred American dollars!

MICROSCOPE SETUP

Fig. 1 shows the QX3™ computer microscope - with a sample of S780 shot particles on the stage positioned on a nylon mesh. Fig. 2 shows the image of those shot particles given by the microscope at 10x magnification with bottom lighting. The microscope is powered from a USB port connected to computer that is USB enabled. The USB hub power needs to be boosted using a standard D.C. transformer and the computer system requirements involve Microsoft®

Windows® 98, 200 MHz or faster processor, 32MB of RAM, minimum 75MB hard disk space, quad speed CD-ROM and 800x600 display with 16-bit colour. All that is involved in operation is to connect the microscope and then insert the CD-ROM. Both "Top" and "Bottom" lighting are available - their relative usefulness will be discussed later. Three magnifications are available, 10, 60 and 200x. A detailed description of the microscope is available on a Florida State University web site, ref. 1.



Fig.1. QX3™ computer microscope - with a sample of S780 shot particles on the stage positioned on a nylon mesh

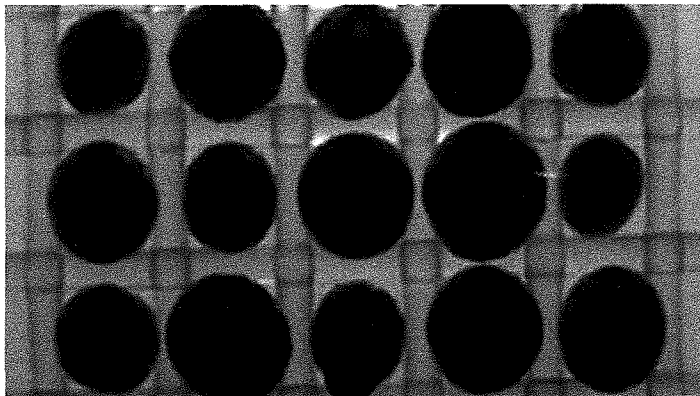


Fig. 2. Sample of S780 shot particles, 10x magnification, bottom lit

SAMPLES, IMAGES and QUALITATIVE ANALYSIS

The first stage in any examination of shot particles is to obtain a sample. For our purposes, it is only necessary to select enough shot to cover a few square centimetres of a containment dish. Two plastic containment dishes are supplied with the microscope but they are easily scratched - especially by grit. The author prefers to use glass microscope slides with a 'glued-on' containment rectangle. Figs. 3 and 4 show samples of unused S780 shot with the image produced using the alternative lighting forms - bottom and top.

The microscope produces colour images, which can be useful but is not normally a requirement for shot particle examination.

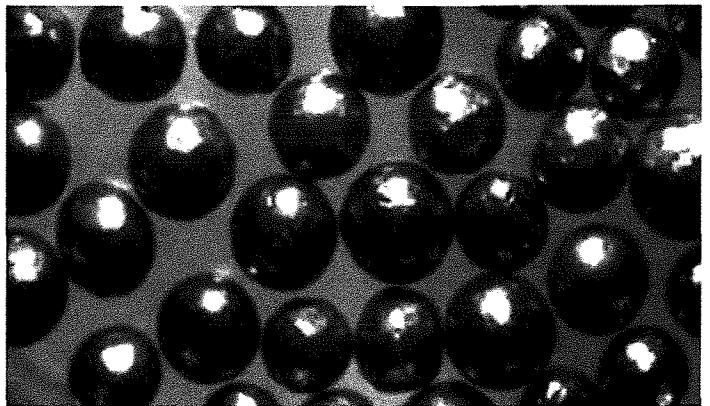


Fig. 3. S780 cast steel shot, top lit, at 10x magnification, 79KB

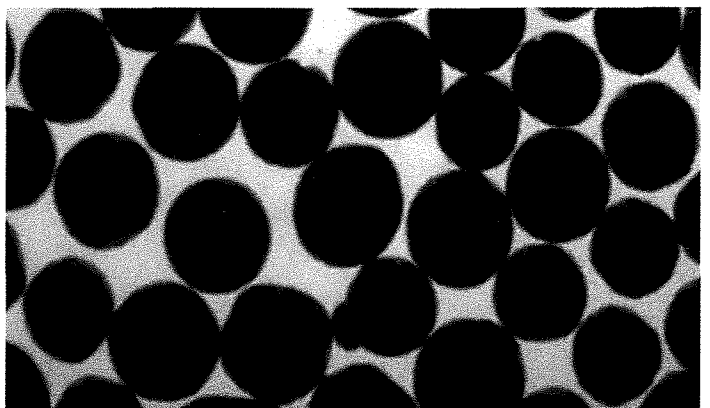


Fig.4. S780 cast steel shot, bottom lit, at 10x magnification, 64KB

The Intel software supplied with the microscope stores images in JPEG format so that the image sizes are very small - useful for storage and internet transfer. Top lighting is good for examining surface damage of particles whereas bottom lighting is much better for quantitative analysis. Both images show that there is a range of sizes and shapes within the samples used. Fewer shot particles can be examined if the particles are physically separated — as in Fig. 2. The support mesh used is simple nylon mesh that is manufactured in a wide range of sizes. For shot particle examination, mesh sizes from 3mm down to 0.5mm

are useful and can be obtained as free manufacturer's samples. One advantage of mesh support is that a semiquantitative estimate of size variation can be obtained directly. It should be remembered that magnifications quoted in publications normally refer to microscope magnifications rather than those appearing on the printed page.

Fig. 5 is a montage of images from different types and sizes of blast particles. They illustrate the quality of image that is presented by the microscope. The images are 'untouched' in terms of enhancement by editing programmes. It should be noted that significantly better images could be obtained by using the methods described in reference 1.

Detailed descriptions of the images in Fig. 5 are not included here since that would extend the scope of this paper beyond its objectives. It is worth noting, however, that the particles being examined are three-dimensional so that it is not possible with any microscope to focus precisely on all parts of any given particle. With bottom lighting it is advisable to focus on the circumference of the particles - especially if quantitative measurements are to be made. With top lighting the focus can be varied to concentrate on particular features of interest, e.g. casting contraction indentations.

Qualitative analysis of images can include comparisons of the change of shape as cut wire is progressively conditioned (see Fig. 5 CCW23, DCW17 and SCW20) and variations of shape and size within a given specimen (see Fig. 5 G18 cf G120). Such analysis is highly 'subjective' (different people coming to different conclusions) which is why quantitative image analysis, being largely 'objective', is generally preferred.

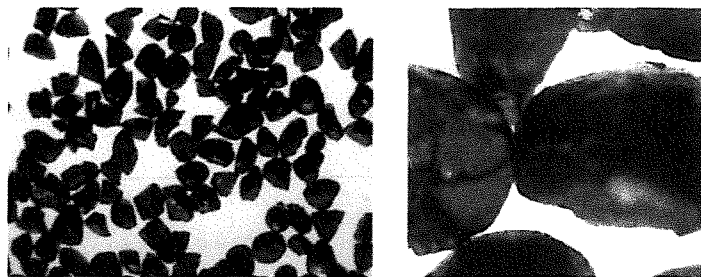
QUANTITATIVE IMAGE ANALYSIS

As with all quantitative measurements, calibration is of prime importance. The onscreen magnification of the shot particles depends on several factors (monitor size, microscope magnification, etc.) so that the actual magnification has to be established. There will also be some degree of image distortion depending on the optical quality of the microscope. The simplest way to establish both magnification and distortion is to project onto the computer screen an image of known dimensions. Fig. 6 shows images of simple rectilinear nets (graph paper) produced using a computer-drawing programme (AutoSketch®) and ink-jet printed onto transparency film. For (a) and (b) the same drawing with 1mm intervals was used but for (c) a drawing with only 0.5mm spacing was used.

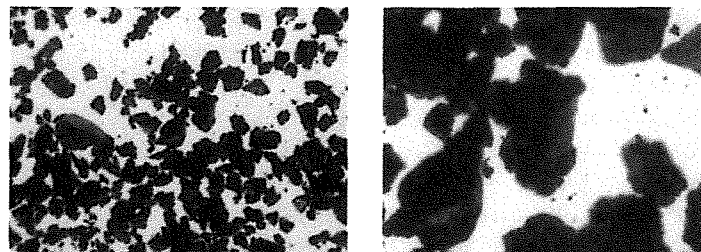
Measurements on the images shown in Fig. 6 show that the full screen widths of the images correspond to approximately 20mm, 3mm and 1mm at the nominal 10x, 60x and 200x magnifications. Some barrelling of the image is noticeable in (a). The actual size of the image on screen depends upon the size of monitor and its adjustment. On the author's 19" monitor, images were always 226mm wide when viewed from within the microscope's software, in Microsoft® Word (at 100%), Adobe Photoshop® and in Aequitas™.

A crude, but effective, way of making quantitative measurements of shot particle dimensions is to apply a flexible ruler to the screen image. Such measurements are divided by the corresponding image magnification (obtained by measuring a calibration image as described previously). A more sophisticated procedure would be to open the image in any available drawing software package and measure the lengths of lines drawn on the

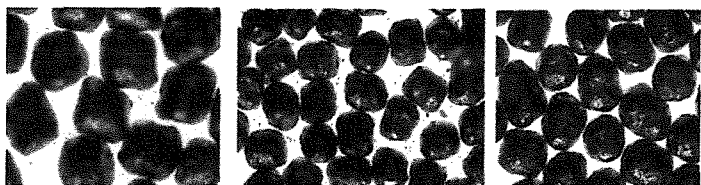
Fig. 5 Montage of images from a variety of blast particles



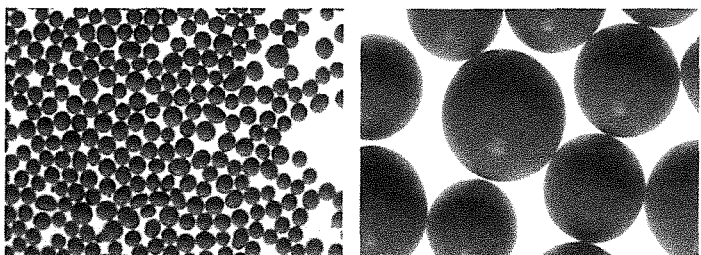
G18 steel grit at 10x and 60x magnifications



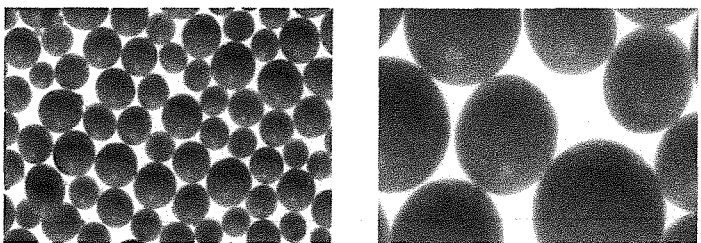
G120 steel grit at 60x and 200x magnifications



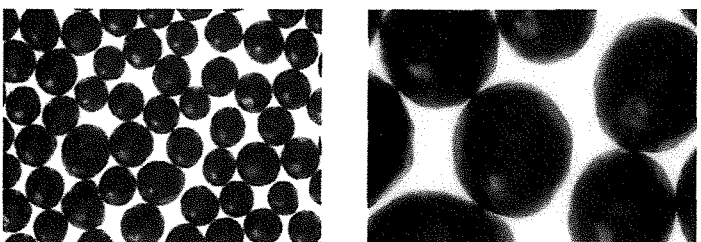
CCW23, DCW17 and SCW20 grades of cut wire shot, all at 60x magnification



B16 zirconia ceramic beads at 10x and 60x magnifications



B40 zirconia ceramic beads at 60x and 200x magnifications



S110 cast steel shot at 60x and 200x magnifications

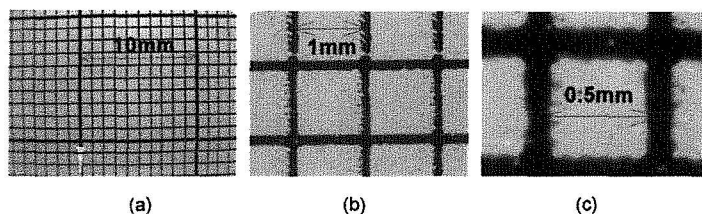


Fig.6. Full-screen images of nets at 10x, 60x and 200x magnification image. By far the most satisfying method, in the author's opinion, is to use an image analysis software programme.

IMAGE ANALYSIS MEASUREMENTS USING AEQUITAS™ IA SOFTWARE

At least two programmes are available at no cost for the software. One 'unrestricted' package is "Image Tool" which can be downloaded from the University of Texas Health Sciences Centre at San Antonio, ref. 2. A second package is Aequitas IA, which is restricted to thirty-minute sessions at a time and can be downloaded from the Dynamic Data Links site, ref. 3. Of the two the author found the latter to be much more 'user-friendly'. Hence, the measurements described hereafter were obtained using Aequitas IA. Aequitas IA is used routinely by at least one major shot producer. The User's Guide should be downloaded for use in conjunction with the programme.

Diameter Measurements

The first step is to 'set calibrate' for each of the three microscope magnifications. A calibration image is opened, see Fig. 6, and the 'Set Calibration' is carried out. This is repeated for the other two microscope magnifications. Thereafter images of shot particles can be opened and diameters measured using the corresponding set calibration (10, 60 or 200x). Pressing 'Measure', 'Lines' and 'Define' allows one to draw lines that represent, say, horizontal diameters for each particle. Right-clicking gives a table of the corresponding values. Pressing 'Edit' and 'Copy' puts those values into the Clipboard from which they can be pasted into spreadsheets of programmes such as Microsoft Excel. A second set of measurements of, say, vertical diameter measurements can then be made. Table 1 shows a set of x and y measurements made on S780 shot, using the image shown as Fig.4, together with values obtained using the procedures mentioned in the next section.

Area, Maximum Diameter, Perimeter and Circularity Measurements

The diameter measurements described in the previous section involve subjective judgements with respect to positioning of the start and end points. Completely objective measurements can easily be made with an image analysis programme. The initial problem is that programmes cannot, of themselves, separate touching particles into discrete objects. With Aequitas IA the threshold has to be set for each image. For shot particles a zero lower threshold and a 150 upper threshold works for most images. With the image in 'Show binary' mode the 'Process' menu allows a binary shrinking of the image by say eleven iterations. The images of each particles shrink as layers are peeled off. This is followed by binary expansion by the same number of iterations with the 'Prevent objects rejoining' box ticked. This results in an image of the shot particles that the computer can now treat as separate objects. Measurement of 'Objects' can then be carried out to determine the required values, see Table 1.

x - mm	y - mm		Max dia. - mm	Circularity	Actual area - mm ²	Perimeter - mm
2.42	2.55		2.35	0.96	4.13	7.43
2.38	2.62		2.17	0.90	3.32	6.75
2.15	2.27		2.42	0.82	3.75	7.16
2.23	2.13		2.59	0.90	4.66	7.88
2.58	2.20		2.67	0.97	5.36	8.53
2.70	2.59		2.31	0.82	3.40	6.80
2.19	2.34		2.66	0.93	5.13	8.23
2.38	2.03		2.43	0.93	4.29	7.62
2.11	2.17		2.19	0.91	3.38	6.77
2.30	2.45		2.45	0.91	4.28	7.59
2.19	2.48		2.35	0.91	3.91	7.19
2.50	2.73		2.55	0.97	4.94	8.14
2.70	2.31		2.64	0.92	4.99	8.11
2.58	2.62		2.91	0.85	5.62	8.68
2.62	2.52		2.68	0.94	5.26	8.39
2.62	2.62		2.31	0.85	3.54	6.98
2.19	2.20		2.62	0.96	5.10	8.20
2.19	2.20		2.21	0.90	3.43	6.87
2.23	2.17		2.25	0.95	3.77	7.09
2.77	2.24		2.72	0.72	4.11	7.68
2.73	2.34		2.31	0.92	3.83	7.19
2.46	2.66		2.74	0.94	5.52	8.60
2.30	2.69		2.79	0.93	5.63	8.69
2.03	2.17		2.21	0.88	3.34	6.74
2.38	2.24		2.19	0.94	3.50	6.85
3.32	2.45		2.83	0.93	5.81	8.85
2.73	2.24		2.70	0.90	5.10	8.41
2.23	2.69		2.64	0.88	4.78	8.05
2.77	2.62		2.63	0.85	4.58	7.83
2.30	2.17		2.35	0.92	3.93	7.31
2.54	2.55		3.47	0.62	5.82	9.12
2.38	2.24		2.43	0.84	3.87	7.31
2.44	2.39	Means	2.52	0.89	4.44	7.72

Table. 1. Image analysis measurements on S780 cast steel shot

The image analysis measurements shown in Table 1 are consistent with qualitative observations on Fig. 4 and with the sieve specification requirement for S780 that there should be a cumulative maximum of 50% with a mesh size of 2.39mm.

DISCUSSION

Within the constraints of a minimal budget, it has been found that useful, reliable and reproducible information can be carried out on shot particle samples. The procedures used are simple and can be carried out without any specific training. First-hand experience of image analysis is also useful if one wishes to progress to more advanced, relatively-expensive, facilities. It is worth noting that commercial image analysis programmes usually cost upwards of one thousand dollars. It is worth considering the purchase of a package, which includes a digital microscope and complimentary image analysis software, e.g. those available at Microscope World; see ref. 4, from \$579.

References

1. <http://micro.magnet.fsu.edu/optics/intelplay/index.html>
2. <http://www.uthscsa.edu/dig/itdesc.html>
3. <http://www.ddlinks.co.uk>
4. <http://www.microscopeworld.com/digital/digital-microscopes.htm>