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AGGREGATE SIZING AND SHAPE DETERMINATION USING DIGITAL IMAGE PROCESSING

N. H. MAERZ

Rock Mechanics and Explosives Research Center, University of Missouri-Rolla

Abstract

Aggregate size and shape measurements are increasingly becoming important issues in the mining, comminution, materials handling, and construction industries.

Screening or sieving methods, today's standard method of sizing stone materials, are simply too inefficient for some applications, excessively time consuming and costly for others, and do not provide enough data for yet other applications. Optical methods using digital image processing, while not ready to replace sieving entirely, promise to replace sieving in some niches, and promise to supplement sieving in others.

Shape measurements are also becoming more important. These are however normally manual measurements, which are prohibitively tedious and subjective. Optical image processing methods also promise to replace these.

1. Introduction

Sizing and shape determinations are increasingly becoming important issues in the materials mining, comminution, handling industries, and in construction industries utilizing stone products. These factors affect the performance of stone products, and need to be optimized. In order to be optimized, they need to be measured in an efficient and cost effective manner.

In the last few years, there has been a proliferation of optically based measurement systems to measure size distributions [1]. One of the earliest of these systems, originally developed at the University of Waterloo [2] [3], is now marketed under the trade name WipFrag [4].



Figure 1. Examples of images used in blasting and milling imaging applications.

These systems have been widely accepted, mostly by the blasting industry for whom there is no practical alternative method for evaluating the size distribution of fragmentation (Figure 1). Screening methods are inconceivable for all but small blasts in a research environment, and are even more unlikely for applications involving large products such as riprap or armorstone. The WipFrag system is also being used for measuring input to milling operations in several Canadian mines (Figure 1). However, optical image processing systems have as of yet not been widely accepted in the aggregate stone industry.

Shape distributions are also becoming increasingly important in the performance of rigid and flexible pavements. Shape measurements today, if done at all, are laborious and tedious manual measurements [5]. Many image processing systems including WipFrag have the capability of measuring particle shapes on two-dimensional views; however it is clear that three-dimensional measurements are needed. An image based method for producing three-dimensional views has been proposed by Frost and Lai [6].

2. Size Measurement

2.1 Requirements

For optical measuring systems to be an effective tool for the aggregate stone industry, they must meet specific requirements.

First and foremost, they must be able to make measurements without disruption of production streaming. This effectively means that materials cannot be handled separately, as they are with sieving methods. Consequently, size determinations must be made on in-place assemblages of aggregates, such as on conveyor belts or at transfer chutes. From an optical measurement point of view this induces a significant amount of uncertainty, because of sampling errors, segregation of material, and simply the

positioning of the aggregate pieces, which in the case of elongated or tabular pieces tend towards laying flat.

Secondly, measurement results must be made and reported in real time, so that adjustments to comminution and screening processes can be made in real time, before large quantities of out-of-specification materials are produced.

Finally, measurements need to be accurate and precise enough to relate to the specifications.

2.2 Capabilities and Limitations of Optical Systems

Sieving, the industry standard for measuring aggregate size distributions, cannot easily be done without disruption of production nor can it report results in real time. If the aggregate material is homogeneous, and only random samples need to be tested, then production need not be disrupted to any great extent, and real time measurements are not so critical.

Optical image processing systems on the other hand do operate in real time, and do not involve any disruption of production. They can operate unobtrusively, and continuously, consequently improving the statistical reliability of the measurement. Measurement results can be easily summarized over short or long terms, making use of moving averages.

Optical systems do however have limitations. They work best on uniformly-colored, flat textured rock, and consequently give better results for dust covered aggregates than for wet, washed aggregates. Optical systems work best for narrow distributions, and in the case of wide distributions, give more accurate results for coarse fragments than for fines. Optical systems tend to measure the intermediate and long diameters of fragments (sieving tends to measure the short and intermediate diameter of fragments), and thus uncorrected results from optical systems tend to overestimate sizes when compared to sieving.

2.3 WipFrag System

The WipFrag granulometry system (Figure 2) accepts images from a variety of sources, such as roving camcorders, on-line fixed-in-place video cameras, digital cameras, photographs, or digital files.

It uses automatic algorithms to identify individual fragments on the image, and measures the profile areas of the blocks. Using principles of geometric probability, WipFrag reconstructs or “unfolds” a three-dimensional distribution [7].

2.3.1 Measurement of In-Place Assemblages

The WipFrag analysis is designed for in-place assemblages. Consequently the problem of partial overlap of fragments viewed on the image is resolved by the unfolding

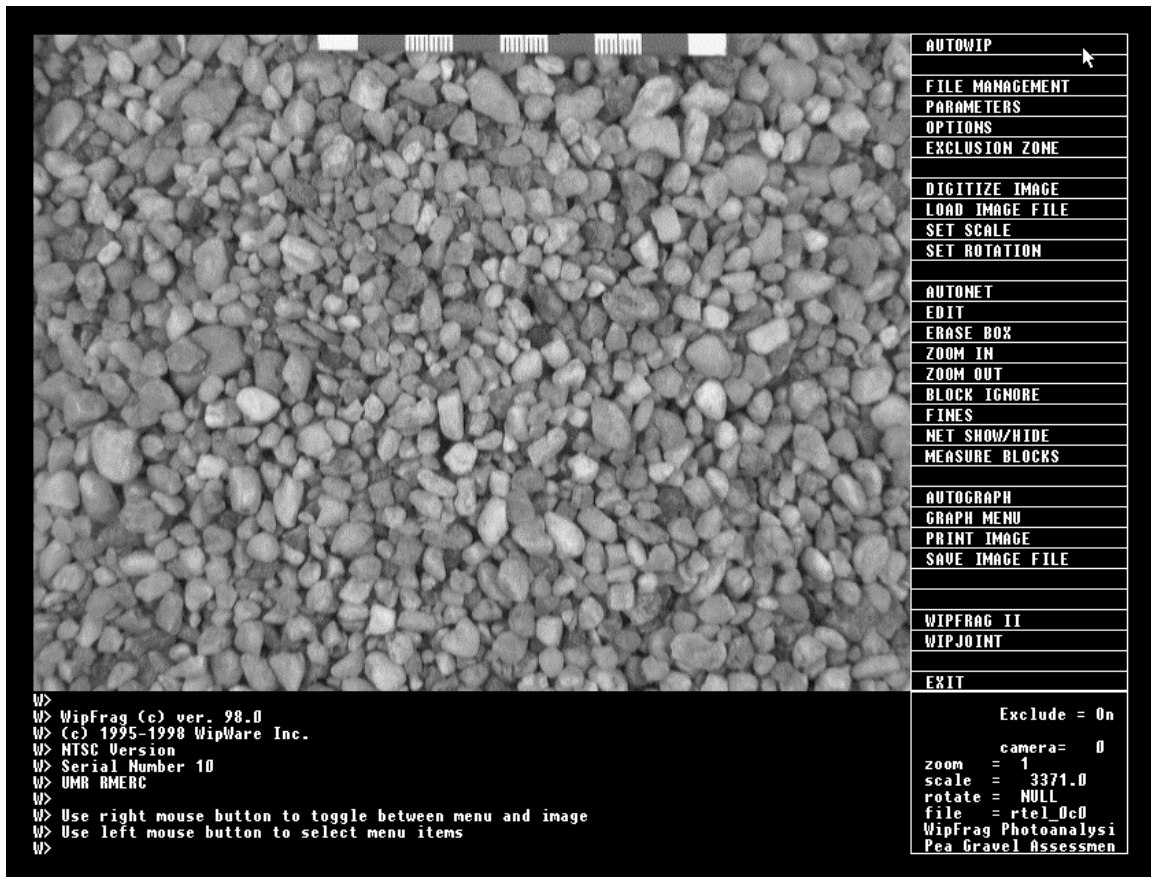


Figure 2. WipFrag system main screen.

function. In addition, some of the “missing fines” (small fragments that fall in and behind larger fragments, or are too small to be resolved on the image) are also accounted for by the unfolding function.

The number of missing fines can however be highly variable, for distributions with variable number of fines, and for various processes that result in different degrees of material segregation by size. For processes such as crushing, the shape of the distributions tends to be constant, and if measured at the same point along the process, the amount of segregation tends to be constant as well. In that case, a missing fines correction, based on empirical calibrations can be employed.

2.3.2 Real Time Analysis

WipFrag analyses take in the order of about 10 seconds for the analysis of a single image. After anywhere between 1 and 20 images are analyzed, summary results can be displayed to the screen, written to disk, or sent to another computer along an RS232 serial

link. Or, control equipment can be signaled directly, using digital TTL or analog 4-20 mA current loop outputs.

2.3.3 Accuracy and Precision

One of the principle provisions of image based systems is that they can only measure what appears on the image, or “what you see on the image is what you get”. WipFrag is no exception to this. Consequently different results from sieving would be expected. The most significant differences come from sampling errors (missing fines) and from flat laying tabular and elongated particles. The expected net result is that optical systems tend to overestimate the size distribution, when compared to sieving results.

Recent studies with aggregate materials have found that accuracy of optical methods can be highly variable, with errors ranging between several to as high as 35% in estimating for example D_{50} , in extreme cases. The same studies have indicated that a reproducibility or precision of 2% is not unreasonable for some aggregates. These studies suggest that the bulk of the errors are systematic and can be removed by careful calibration.

2.3.4 Aggregate Applications

A small study was done at a limestone quarry. In it a crusher run product was imaged on stock piles, on the belt, and falling off the end of the belt (Figure 3). Despite the seemingly poorer picture quality of the images falling off the end of the belt, the measurement results were closest to the sieving results, presumably because the fines were more visible in these images.

3. Shape Measurement

3.1 Requirements

The requirements for shape measurement are quite different than the requirements for sizing. In making shape measurements, the requirement to do in-place measurements is not practical.

Studies using the WipFrag system have indicated that measuring shapes of partially overlapped particles is not useful. The measured shape of these overlapped fragments is remarkably constant despite there being actual differences in the shape of the particles. It seems that the overlap obscures the actual shape sufficiently to make this a fruitless exercise.

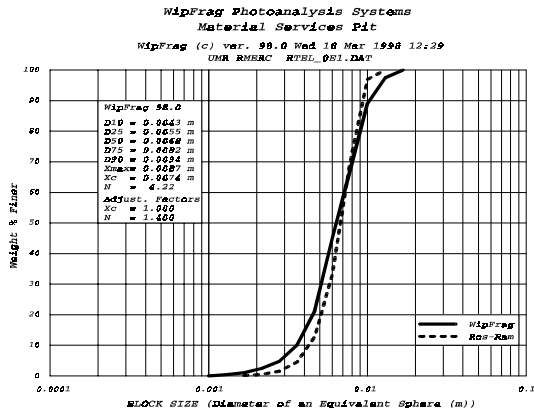
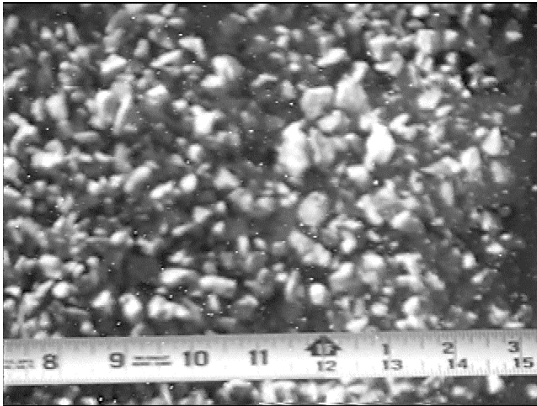
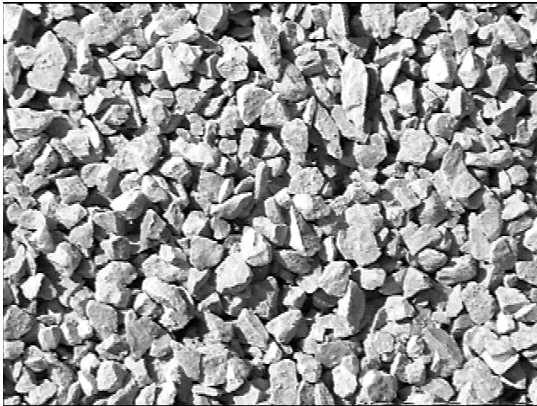


Figure 3. Images of the same crusher run product. Top left: In stockpile. Top right: On moving conveyor belt. Bottom left: Falling off end of conveyor belt. Bottom right: Measured size distribution vs. Rosin-Rammler fit of sieved distribution.

3.2 WipFrag Shape Measurements

The WipFrag code was modified to image individual blocks in an assemblage where they were spread out over a backlit table. Using this approach, two-dimensional shape measurements are possible (Figure 4).

The problem with this approach is that particles tend to lay flat, consequently it is usually the most critical dimension of the particle that is not measured. This approach has been rejected by the industry as being inadequate.

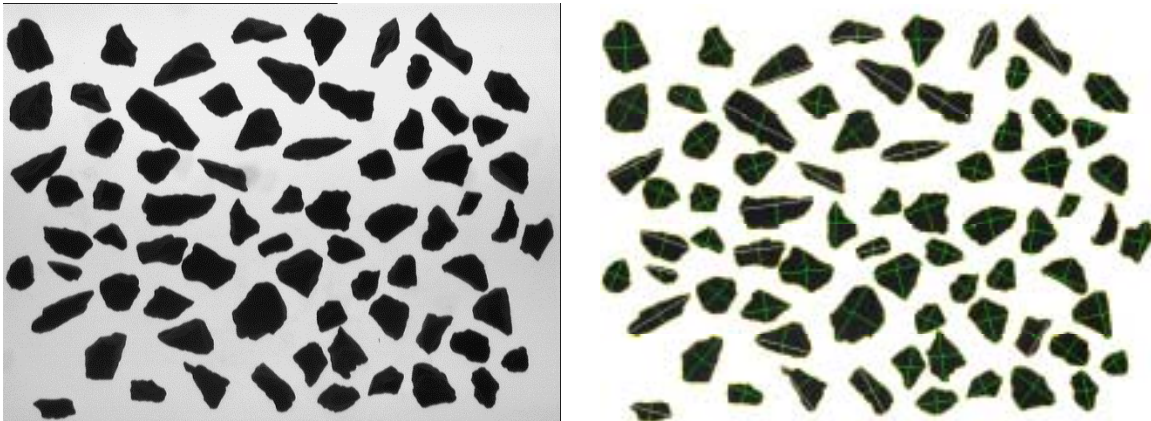


Figure 4. Two-dimensional shape measurements on distributed aggregate samples.

3.3 WipShape Developments

Currently, a new approach is being formulated. A new measuring system called WipShape is currently under development. It is predicated on the principle that each particle must be imaged separately, and from two views.

A prototype mini-conveyor system has been developed to parade individual fragments past two orthogonally oriented synchronized cameras (Figure 5). This is fed by aggregates from a hopper, and each fragment is imaged individually, and then analyzed by computer.

When completed, the systems will be capable of continuous automated operation. It will measure various shape factors, including principle axis ratios, roundness, and sphericity and angularity. Simultaneously it will produce size distribution curves, and shape measurement summaries by size classes. Research will be conducted to determine if the percentage of fractured faces can be measured.

When completed, this promises to be a useful tool for characterizing aggregate products.

4. Conclusions

Image processing and analysis techniques have become sophisticated enough to address some of the needs of the mining, comminution, and materials handling industries. In the future, with more research and development, and increased industry experience, the utility of these types of methods will increase dramatically, and play an increasing role in production analysis and control.

Project: Full scale testing facility



The requirement of this project is to install a WipFrag conveyor system at a local quarry, to measure the

Figure 5. Left: Prototype of a shape measuring system. Right: Top and side view of an elongated aggregate.

5. References

1. Franklin, J. A., Kemeny, J.M. and Girdner, K. K. Evolution of measuring systems: A review. *Proceedings of the FRAGBLAST 5 Workshop on Measurement of Blast Fragmentation*, Montreal, Quebec, Canada, 23-24 Aug., pp. 47-52 (1986).
2. Maerz, N. H., Franklin, J. A., Rothenburg, L. and Coursen, D. L. Measurement of rock fragmentation by digital photoanalysis. *ISRM. 6th Int. Cong. on Rock Mechanics*, Montreal, Canada, v 1, pp. 687-692 (1987).
3. Maerz, N. H., Franklin, J. A. and Coursen, D. L. Fragmentation measurement for experimental blasting in Virginia. *S.E.E., Proc. 3rd. Mini-Symposium on Explosives and Blasting Research*, Miami, Feb. 5-6, pp. 56-70 (1987).
4. Maerz, N. H., Palangio, T. C. and Franklin, J. A. WipFrag image based granulometry system. *Proceedings of the FRAGBLAST 5 Workshop on Measurement of Blast Fragmentation*, Montreal, Quebec, Canada, 23-24 Aug., pp. 91-99 (1996).

5. ASTM. Standard test method for flat particles, elongated particles, or flat and elongated particles in coarse aggregate. ASTM D4791-95 (1995).
6. Frost, J. D. and Lai, J. S. Digital Analysis of Aggregate Particle Shape. *Center For Aggregates Research, Fourth Annual Symposium, Atlanta, GA, April 14-17 (1996).*
7. Maerz, N. H. Reconstructing 3-D block size distributions from 2-D measurements on section. *Proceedings of the FRAGBLAST 5 Workshop on Measurement of Blast Fragmentation, Montreal, Quebec, Canada, 23-24 Aug., pp. 39-43 (1996).*