PARTICLE SIZE AND SHAPE ANALYSIS OF GLASS BEADS FOR PAVEMENT MARKINGS

Summary

Glass beads are used in a wide range of industrial applications. Street signs and pavement markings use glass beads to increase light reflection at night. The size and shape of the bead is critical to its reflective characteristics. Measuring the size and roundness of beads can be a time consuming process involving multiple measurements and multiple techniques. The Camsizer Digital Image Processing analyzer combines size classification and roundness characterization into one easy, automated measurement.

Introduction

In 1930, J.D. Millar, an engineer with the Ontario Department of Transport, dreamed up the idea of using a white line to separate the lanes of a highway. The first white line was painted on a stretch of highway near the Ontario-Quebec border. Within three years, Millar's white line was a design standard in all of North America. Today's pavement markings offer significantly improved nighttime visibility through the use of glass beads embedded into the paint. The light from the vehicles' headlights is reflected back to the driver from the glass beads in the paint, causing the striping to appear illuminated.

During application, glass beads are dropped into wet paint directly behind the paint sprayer. They are enveloped by the paint, due to the wicking action of the paint, ideally rising up to about 60% of the diameter of the bead. The paint retains the beads securely and acts as a mirror surface. The light entering the glass bead is bent, focused toward the back of the bead, and then reflected back out toward the driver.

Aside from the issue of paint quality and application density, the quality of the glass beads have a significant impact on retro-reflectivity performance. The glass beads should be round and clear, with little scatter or filtering. The more perfectly round the bead, the more the light reflects back to its source, providing visibility of the marking in low-light conditions.

Manufacturing glass beads from cullet

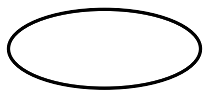
The manufacturing process for glass beads starts with crushed glass called cullet. This is screened into different size classes. Each size class is used to make a different size glass bead. The cullet is introduced to a furnace which melts the glass and (ideally) forms spheres. The spheres fall out of furnace and are collected. The manufacturing process has a number of problems with non-round beads. It is important to control this process and to qualify the material.

Camsizer Particle Size & Shape Analyzer

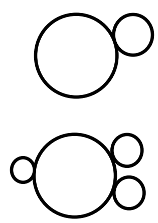
Good Beads, Bad Beads

The object is to make a perfectly round glass bead. A perfect sphere without air inclusions gives the best retro-reflectivity. The type of defects normally found in beads fall roughly into the following categories:

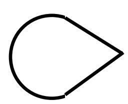
- Oval particles:
  If the ratio between the larger and smaller diameter (breadth/length) is greater than 1.3 the particle is defined as oval and hence defective.



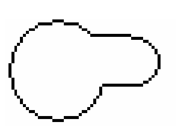
- Satellites / Planets During the final stages of cooling, particles can collide and attach to each other. If a particle carries more than two satellites or if a single satellite is bigger than 25% of the size of the "mother" bead, then the particle is considered defective.



- Pointed particles A defect similar to oval particles, an aspect ratio greater than 1.3 is declared as defective.



- Aggregates
  These particles are melted satellites.



Current Methods of size and shape analysis

Historically sizing of glass beads has been done by sieving. ASTM method D1214 (1994) outlines the sieving procedure. For larger beads, roundness has been historically determined by microscopy. The sieved fractions are analyzed by hand, usually counting out 100 particles and viewing them, counting the defects. The results of the small sample are related to the bulk material and the result is a percentage of non-round particles per sieve cut.

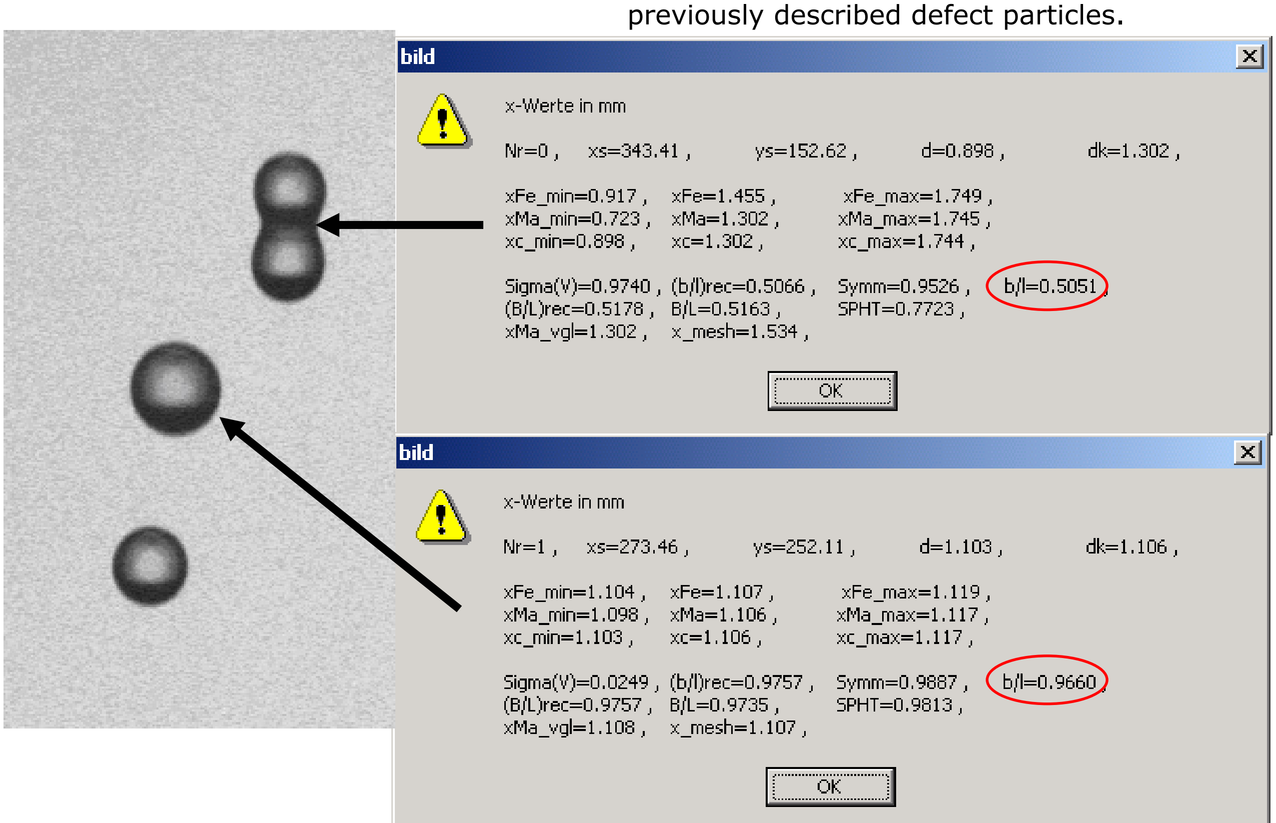
Roundness of smaller beads has been measured by the Round-o-Meter following ASTM method D1155-89. This instrument uses a vibrating inclined glass plane. The round particles roll down and the non-round stay in place or roll backward, so that a separation of round and non-round particles is possible. The total analysis time is long because each sieve class has to be measured separately and requires accurate sampling because of the small sample size. Sample metering to the Round-o-Meter and careful adjustment of the Round-o-Meter's tilt and vibration intensity depend on the size of the beads being measured and can have a significant influence on the data. The results for both microscopy and the Round-o-Meter are not very reproducible and are very operator dependent.

The Camsizer method provides a higher quality of data and faster results because it can do both size classification and a roundness measurement at the same time. In addition it has much higher resolution than traditional methods. Reproducibility is dramatically improved because the user can test a sample as large as two liters (hundreds of thousands of particles).

This avoids the need to split the sample entirely. The user simply fills the hopper with the sample, presses measure and the beads are metered into a measuring shaft between a light source on one side and two cameras on the other. The sample is collected below in a removable sample tray. Analysis time is on the order of a few minutes.

In addition to the relative amounts of round vs. non-round particles, the complete shape analysis of every particle in the sample provides a more detailed picture of the manufacturing process performance. It can also identify defect particles such as cylinders that will roll on the Round-o-Meter and be reported as round.

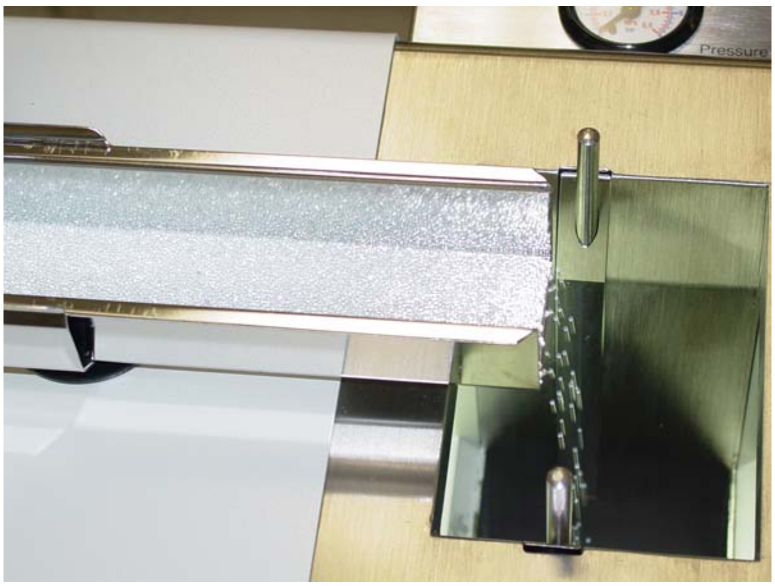
In the following figure we displayed an image taken during a measurement. The image displays some of the previously described defect particles.



The analysis of the two particles shows the significant difference in the measurement parameters between the round particle and the doublet. This analysis is done automatically for each particle presented in the measurement zone.

Analytical test method
Use sample director to ensure beads are within the focal plane during measurement.
Obscuration: 1%
Model: minXc
Statistical measures:

- To determine round vs. non-round – (1-Q3) b/l threshold for shape classification column. The CAMSIZER® can detect this by using the threshold value 0.77 for the b/l ratio. To correlate to existing Round-o-Meter results, this value usually needs to be different for each size class.
- To determine satellites or aggregates - using the convexity parameter with a threshold at 0.95.



Measurement of glass beads on the Camsizer

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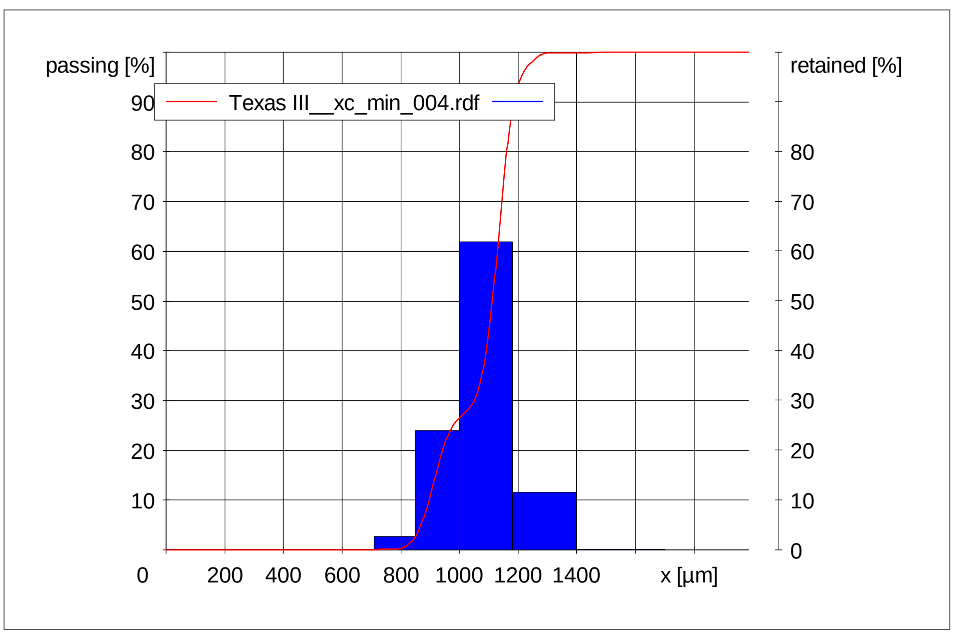
HORIBA CAMSIZER® Retsch® TECHNOLOGY

QUALITY REPORT

Company:	Horiba Instruments
User:	bws
Result file:	C:\Program Files\CAMSIZER-330c\CAMDAT\Weissker\Texas III__xc_min_004.rdf
Task file:	C:\Program Files\CAMSIZER-330c\CAMSYS\Weissker_txtype3_.afg
Time:	11.2.2004 , 4:26 , duration 9 min 21 s at 0.5 % covered area, image rate 1:1 and 40 mm feeder
Particle model:	min(xc)
No. of particles:	CCD-B = 227015 , CCD-Z = 17467
Fitting:	no
Material:	

ASTM(+)	No(-)	retained [%]	passing [%]	SPHT3	l/b3	particle count	1-Q3(b/l) 0.8300
> #12		0.00	100.00	0.533	1.409	3	0.00
#14	#12	0.09	100.00	0.887	1.197	61	62.84
#16	#14	11.56	99.91	0.977	1.028	21551	93.34
#18	#16	61.82	88.35	0.986	1.033	118786	97.96
#20	#18	23.86	26.53	0.983	1.041	95648	97.34
#25	#20	2.62	2.67	0.872	1.112	3669	81.26
PAN	#25	0.05	0.05	0.642	1.237	4573	57.18



Characteristics

Q3 [%]	x [µm]
10.0	897
50.0	1112
90.0	1185

SPAN3 = 0.259
U3 = 1.259
MW3(x) = 1075 µm
Sigma3(x) = 112 µm

User