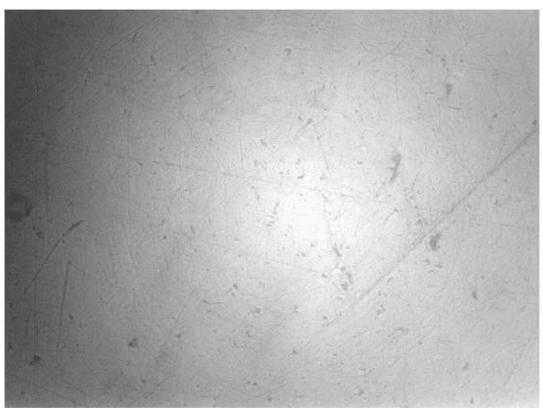
---

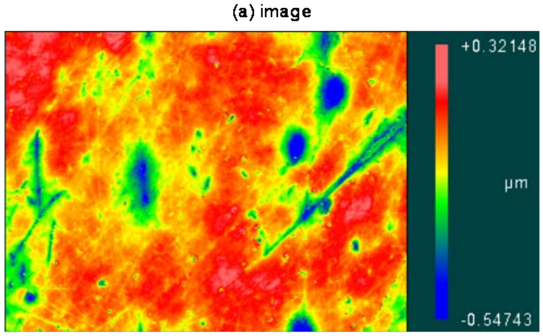
*Supporting narrated video (NV) demonstrations, high-speed video (HSV) clips, technical proofs (TP), and all of my past articles can be viewed online at **billiards.colostate.edu**. The reference numbers used in the articles help you locate the resources on the website. If you have a slow or inconvenient Internet connection, you might want to view the resources from a CD-ROM or DVD. Details can be found online at: **dr-dave-billiards.com**.*

Most of us think of pool balls as very smooth, but how smooth are they? Well, I decided to find an accurate answer to this question, so I visited the surface metrology laboratory on my university campus. Fortunately, the Lab has a scanning white light interferometer (SWLI) that enabled me to capture some high-resolution images of pool ball surfaces under extreme magnification. The SWLI not only captures visual images of the surface, but it also measures surface height at each pixel in the visual image.

Diagram 1 shows an image and elevation contour map of a magnified 1 millimeter by 1 millimeter area on a new and clean Aramith cue ball (CB). Pool balls are usually cast from and coated with a hard plastic phenolic resin and then polished smooth (see the links in the "ball material and manufacturing" section of my website FAQ page for more info). The plentiful scratches visible in image "a" are from the polishing portion of the manufacturing process, and the blemishes and pits are probably slight defects in the cast/coated resin material. When magnified and imaged, a CB's surface isn't as smooth as you might have thought it was, is it? The elevation contour map shown in "b" displays the relative heights of the small peaks and valleys on the surface. The reddish colors indicate high features, and the bluish colors represent low features, with yellows and green in the middle. If you focus on the big scratches in image "a," you can see the correspondence in "b." On this portion of the CB surface, the measured peak-to-valley range was +0.32 to -0.54 μm, per the scale on the right side of "b." A μm is a micron or micrometer, which is a millionth of a meter or about 40 millionths of an inch! The SWLI can obviously measure very small heights and depths on the surface.



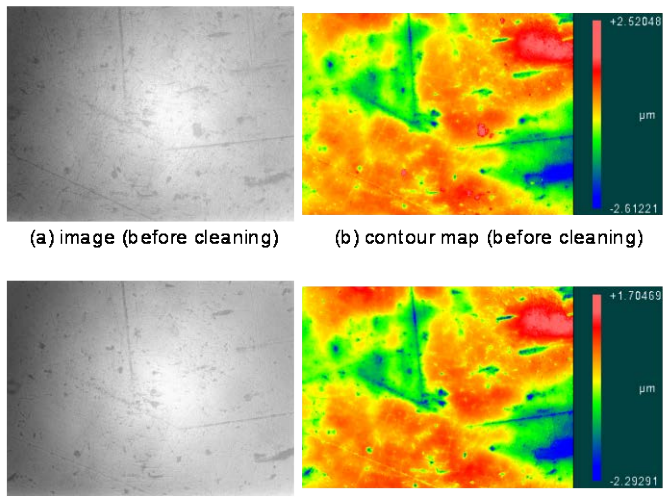
(a) image



(b) contour map

Diagram 1 New and clean CB surface

Diagram 2 shows the image and elevation contour map for an old CB that had been used for about a year and had not been cleaned recently. Images “a” and “b” are of the ball without any preparation, and images “c” and “d” are from the same area on the ball, but after cleaning. The surface was cleaned with an alcohol-base solvent, using a cotton swab to rub and wipe across the area. There appears to be only subtle differences in the images before and after cleaning; however, some of the features (“dirt”) in image “a” are obviously missing in image “c”. Notice that the peak-to-valley range is smaller in image “d” (+1.70 to -2.29 μm) compared to that in image “b” (+2.52 to -2.61 μm). Both of these ranges are larger than the range for the new ball in Diagram 1. This could be a result of the wear resulting with use, but it could also just be a typical difference from one ball to the next or from one area on the surface to the next.

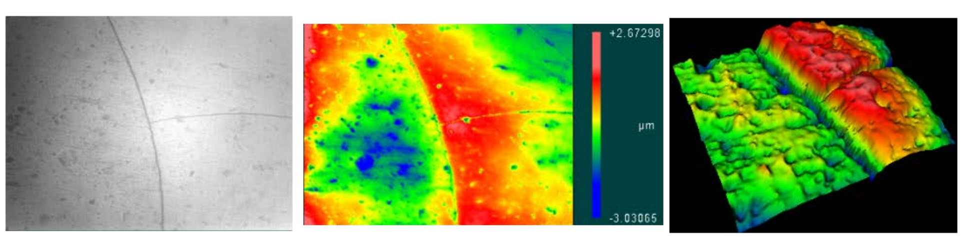


(a) image (before cleaning) (b) contour map (before cleaning)

(c) image (after cleaning) (d) contour map (after cleaning)

Diagram 2 Used and dirty CB surface, before and after cleaning

Diagram 3 shows images for an Elephant Practice Ball, which is made from polyester instead of a phenolic resin. Notice the clearly visible long cracks on the surface. (BTW, the cracks were not visible to the naked eye.) The cracks might be a result of the manufacturing process (for example, when the outer coating shrinks due to cooling or drying), but they could also be fractures resulting from use. Regardless, I didn’t see any features like this in any of the phenolic balls I imaged. The peak-to-valley range on the Elephant Practice Ball (+2.67 to -3.03 μm) was the largest of all of the measurements made. Image “c” is a three-dimensional (3D) version of the elevation contour map in “b.” In the 3D image, the cracks are reminiscent of fault lines in the Earth’s crust, where the red portion on the right is a higher “mountain-like” area lifted above the “plain-like” green and blue portion on the left.

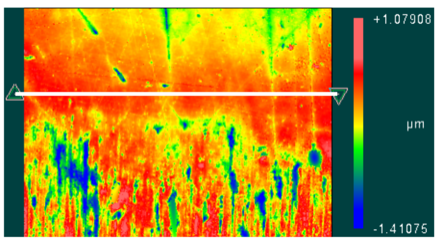


(a) image (b) contour map (c) 3D contour map

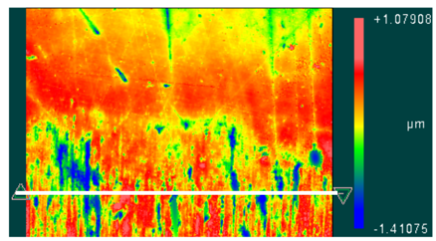
Diagram 3 Elephant Practice Ball

Diagram 4 shows the image of an Aramith CB with a scuff mark that was probably caused by a miscue. The abrasions on the surface clearly visible in the bottom of image "a," are evidence of the scuff mark that was visible to the naked eye. Also shown are elevation contour maps with line plots through two different cross sections, one through the non-scuffed and relatively smooth area (images "b" and "d"), and one through the middle of the scuff (images "c" and "e"). Obviously, the scuffed area has a much larger peak-to-valley range, as would be expected. Also note that the peak-to-valley range for the scuffed ball (+1.08 to -1.41 μm) is much larger than the baseline test shown in Diagram 1 (+0.32 to -0.54 μm).

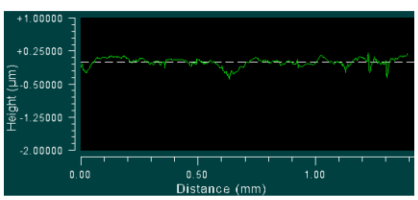
(a) image



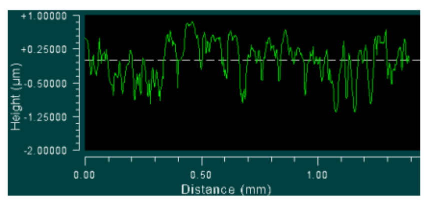
(b) contour map showing non-scuffed section line



(c) contour map showing scuffed section line



(d) line plot (non-scuffed section)



(e) line plot (scuffed section)

Diagram 4 CB with a scuff mark

So, based on the data, just how smooth is a CB? And how does this smoothness compare to the surface of the Earth? The highest point on earth is Mount Everest, which is about 29,000 feet above sea level; and the lowest point (in the earth's crust) is Mariana's Trench, which is about 36,000 feet below sea level. The larger number (36,000 feet) corresponds to about 1700 parts per million (0.17%) as compared to the average radius of the Earth (about 4000 miles). The largest peak or trench for all of the balls I tested was about 3 microns (for the Elephant Practice Ball). This corresponds to about 100 parts per million (0.01%) as compared to the radius of a pool ball (1 1/8 inch). Therefore, it would appear that a pool ball (even the worst one tested) is much smoother than the Earth would be if it were shrunk down to the size of a pool ball. However, the Earth is actually much smoother than the numbers imply over most of its surface. A 1x1 millimeter area on a pool ball (the physical size of the images) corresponds to about a 140x140 mile area on the Earth. Such a small area certainly doesn't include things like Mount Everest and Mariana's Trench in the same locale. And in many places, especially places like Louisiana, where I grew up, the Earth's surface is very flat and smooth over this area size. Therefore, much of the Earth's surface would be much smoother than a pool ball if it were shrunk down to the same size.

Regardless, the Earth would make a terrible pool ball. Not only would it have a few extreme peaks and trenches still larger than typical pool-ball surface features, the shrunken-Earth ball would also be terribly non round compared to high-quality pool balls. The diameter at the equator (which is larger due to the rotation of the Earth) is 27 miles greater than the diameter at the poles. That would correspond to a pool ball diameter variance of about 7 thousandths of an inch. Typical new and high-quality pool balls are much rounder than that, usually within 1 thousandth of an inch.

Good luck with your game,
Dr. Dave

PS:

- I want to thank Jack Clark of Surface Analytics, who runs the surface metrology Lab at my university. The equipment we used was a Zygo New View 7300 Scanning White Light Interferometer (SWLI).
- I know other authors and I tend to use lots of terminology, and I know not all readers are totally familiar with these terms. If you ever come across a word or phrase you don't fully understand, please refer to the online glossary on my website.

Dr. Dave is author of the book, DVD, and CD-ROM: "The Illustrated Principles of Pool and Billiards," and co-author of the DVD Series: "Video Encyclopedia of Pool Shots (VEPS)" and "Video Encyclopedia of Pool Practice (VEPP)."