Investigation of Shaped Abrasive Particles Vol. 1: Review of US Pat. No. 6,054,093 April 25, 2000

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Introduction

Shaped abrasive particles have been known and utilized in various capacities within the field of grinding and finishing technologies for over 15 years. Shaped abrasive particles disclosed in US Pat. No. 6,054,093 (hereinafter the "'093 Patent") are formed through a screen printing process, referred to as the Torre Process. The following review characterizes the Torre particles formed according to Example 1 as described in the '093 Patent.

The following characteristics of the Torre particles include:

- The *radius of curvature*
- Grooves and protrusions including the *ratio between the groove depth and average thickness*
- Raised corners including the ratio *between the corner thickness and midpoint thickness*
- Perpendicular, obtuse, and acute angles between the surfaces

Characterization of Historic Shaped Abrasive Particles

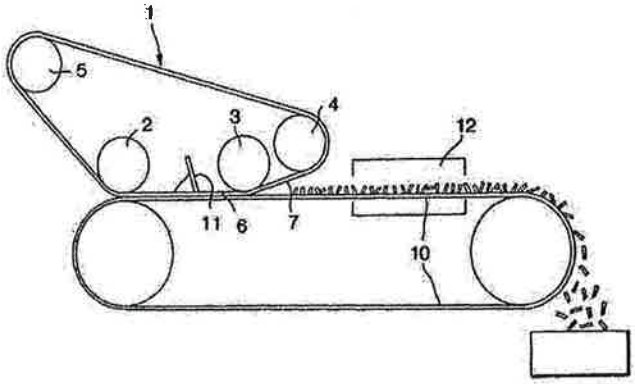

FIG. 1. Screen printing process for forming shaped abrasive particles from '093 Patent.

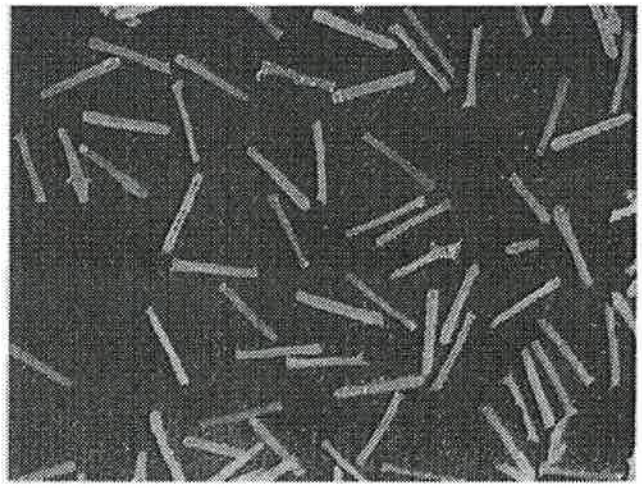

FIG. 2. Shaped abrasive particles from the Torre Process.

Characterization studies were carried out on shaped abrasive particles obtained from the method disclosed in Example 1 of the '093 Patent. FIG. 1 and FIG. 2 are illustrations from the '093 Patent. FIG. 1 is a generalized schematic of a screen printing process. As described in the '093 Patent, FIG 2 (reproduced below) illustrates abrasive particles from a sample produced in accordance with FIG. 1. Particles from that same sample are evaluated throughout this document.

Surface Features

The abrasive particles exhibited a variety of surface contours. FIG. 3 below provides a magnified image of two printed abrasive particles having unique contours.

The shaped abrasive particle of FIG. 3 labeled 300 has a bowed contour, such that the shaped abrasive particle generally has a scoop-shape. Particle 300 has opposing major surfaces 301 and 302, which define concave and convex curvatures, respectively. The concave and convex curvatures are identified relative to a linear axis 303 drawn through the middle of particle 300, along the length.

To fully understand the extent of the curvature intrinsic to the shaped abrasive particles, the authors measured the radius of curvature of

surface 301 of particle 300 shown in FIG. 3. A best fit circle was fitted to the arcuate surface 301 using computer imaging software, ImageJ, available at http://rsbweb.nih.gov/ij/. The radius of curvature of surface 301 was calculated to be approximately 5 mm.

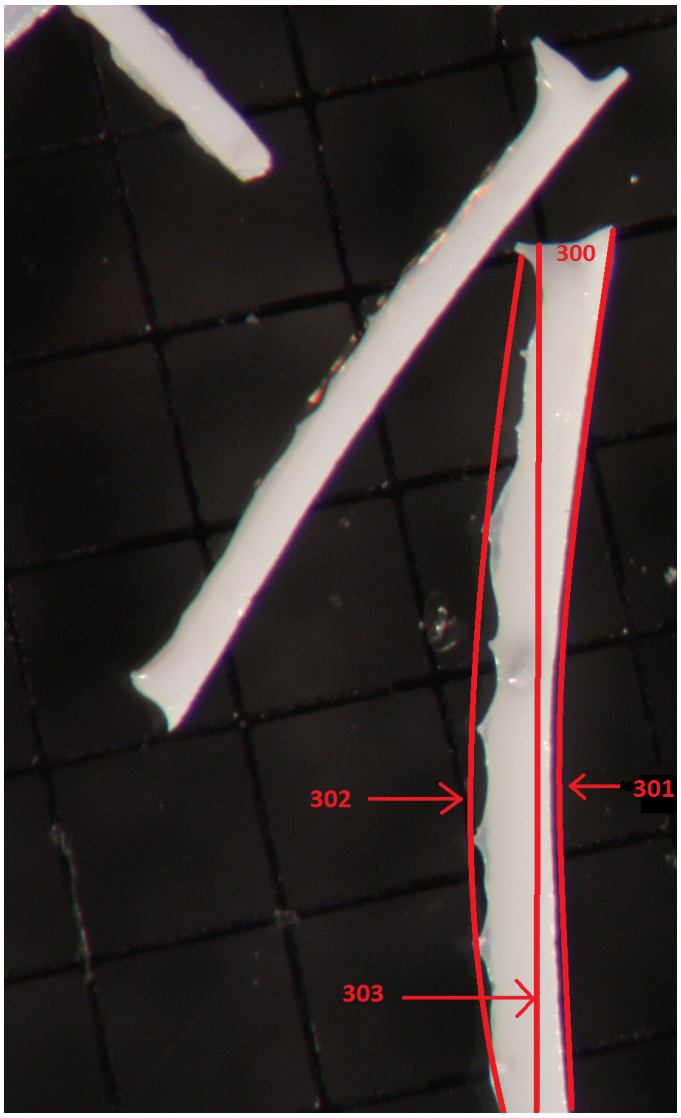

FIG. 3. Magnified image of shaped abrasive particles from Example 1 of the '093 Patent.

Other surfaces of the shaped abrasive particles were also observed as having interesting curvatures. FIG. 4 provides a cross-sectional illustration of an abrasive particle as viewed in a plane perpendicular to the length of the particle. As illustrated, the top surface 402 of the abrasive particle 400 has a concave contour. The bottom surface 403 also demonstrated some curvature. However, the curvature of the bottom surface 403 was significantly less than the curvature of the top surface 402, more nearly approximated to a flat surface. Furthermore, it is interesting to note the side wall surfaces 404 and 405 of the particle 400 demonstrated significant curvatures upon transitioning from the upper surface 402 to the bottom surface 404.

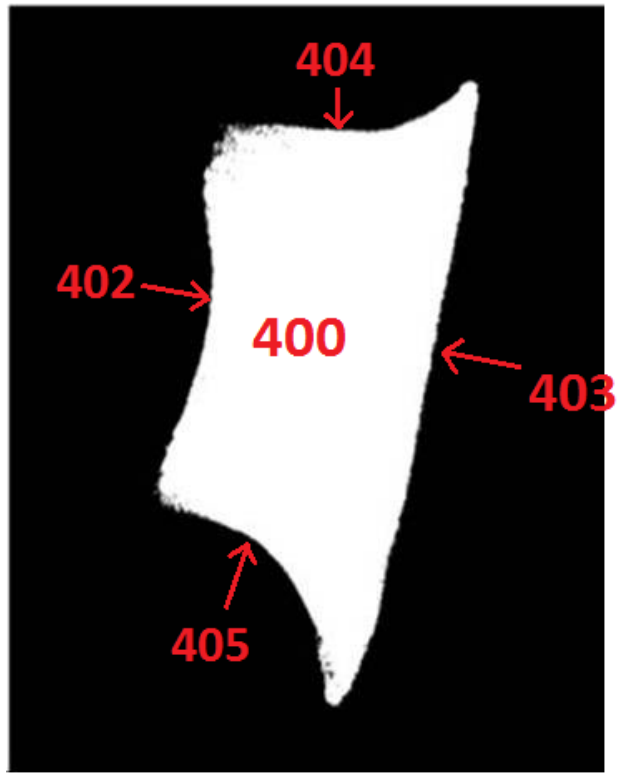

FIG. 4. Cross-sectional view of a Torre abrasive particle.

It was further noted that the shaped abrasive particles exhibited grooves and protrusions along certain surfaces. Referring again to FIG. 3, the particle 300 has grooves and protrusions on the surface 302. The grooves and protrusions appear to have regularity, indicating that such features are likely artifacts of the forming process.

To more fully understand the characteristics of the grooves, measurements were made on particle 300 using ImageJ imaging software. The depth (D) of the grooves was measured as the distance taken from a midpoint from a straight line drawn between two immediately adjacent protrusions to the surface 302 of the particle 303. FIG. 5 provides an illustration of the measurement technique. The average thickness (t) of the abrasive particle 300 was also determined by making 11 individual measurements across the thickness of the particle 300 at random locations along the length. The ratio between the average depth of the grooves

and the average thickness of the particle 300 was approximately 0.2.

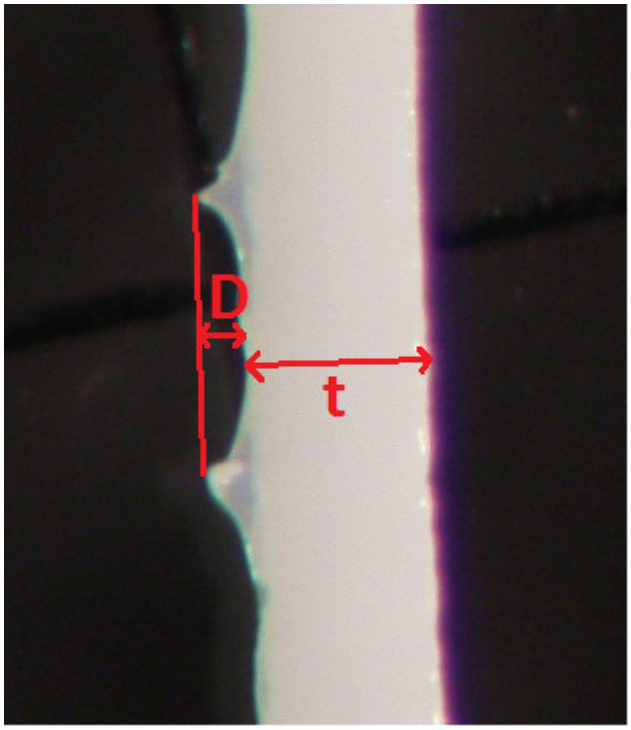

FIG. 5. A magnified image of the abrasive particle of FIG. 3 illustrating the depth of a groove, D, and approximate thickness, t.

Edge and Corner Features

It is interesting to note that the historic shaped abrasive particles formed from the Torre Process had unique edge and corner features. In fact, certain edges and corners of the shaped abrasive particles demonstrated contours that gave the particle a sharpened profile.

As illustrated in FIGs. 6a and 6b, the shaped abrasive particles had inherently raised corners, such that the thickness of the particles at the corners (t_c) was significantly greater than the thickness at the midpoint (t_m). Measurements of the thickness at various portions of the particles were conducted on the particles using the pictures provided in FIGs. 6a and 6b using ImageJ imaging software. FIG. 6c provides an illustration of the dimensions examined for each particle. The ratio between the thickness of the corners and thickness of the particles at the midpoint (t_c/t_m) was calculated as 1.7.

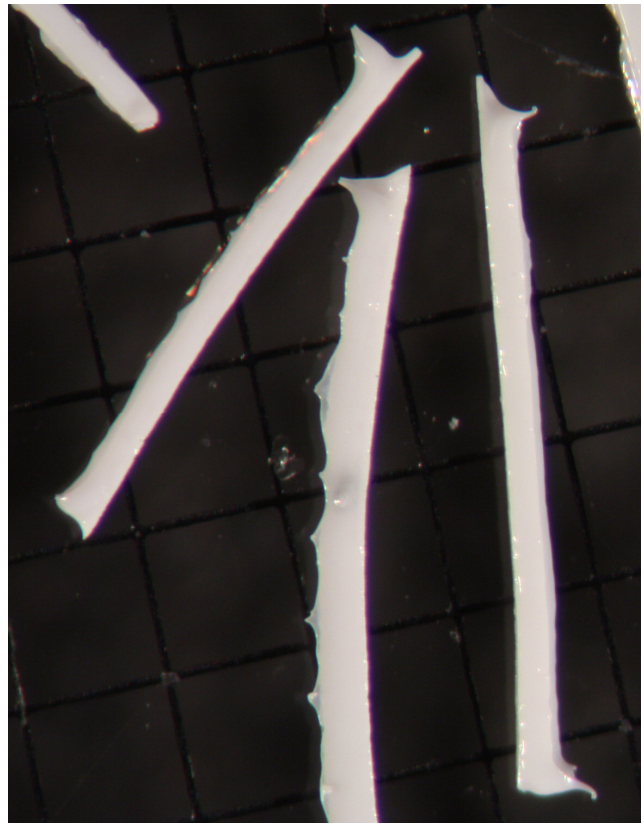

FIG. 6a. Images of shaped abrasive particles having raised corners.

FIG. 6b. Images of shaped abrasive particles having raised corners.

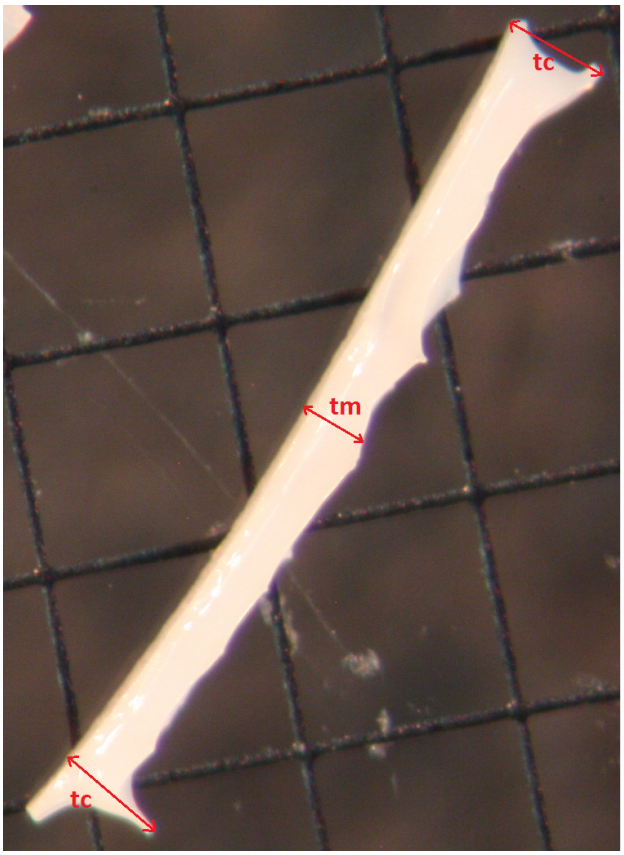

FIG. 6c. Image of dimensions of corner thickness (t_c) and midpoint thickness (t_m) of a shaped abrasive particle.

Furthermore, in reviewing the shaped abrasive particles from the '093 Patent, it was discovered that a wide variety of angles existed at the corners. Some particles exhibited a perpendicular or nearly obtuse angle between the upper surface and side surface. See, for example, FIG. 7a demonstrating various angles at different corners for the cross-sectional view of the particle in FIG. 3. As illustrated, the angle A1 between the upper surface and the side surface is generally an obtuse angle, while the angle A2 is generally a perpendicular angle, and angle A3 and A4 define acute angles.

As illustrated in FIG. 7b, certain corners of the shaped abrasive particle of FIG. 3, as viewed in cross-section, appear to have a rounded contour.

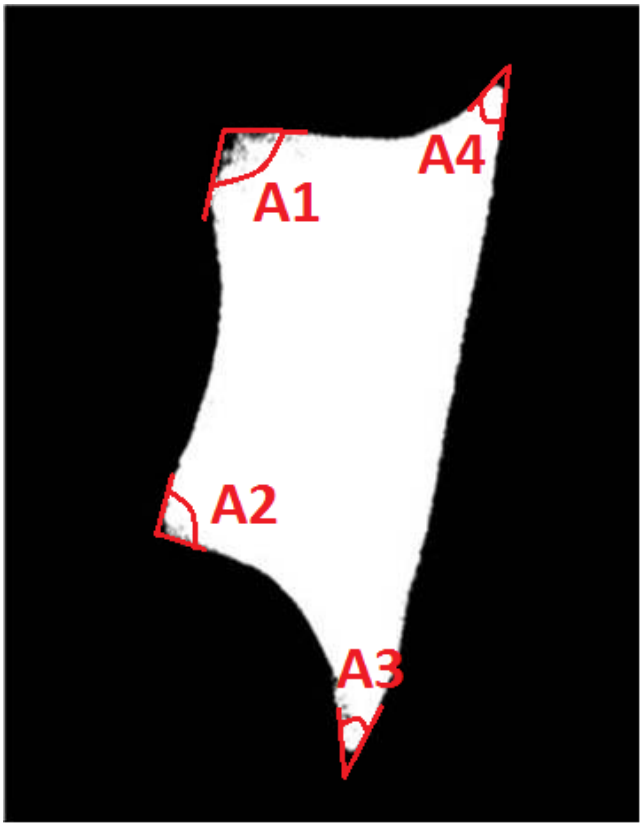

FIG. 7a. Image of a shaped abrasive particle having 4 different angles (A1, A2, A3, and A4) at 4 corners as viewed in cross-section.

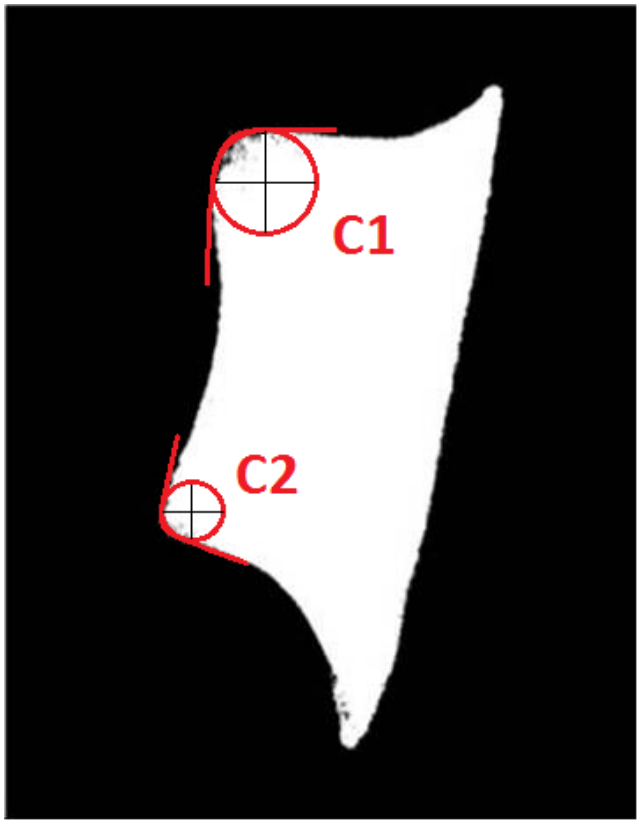

FIG. 7b. Image of the shaped abrasive particle of FIG. 3 demonstrating rounded upper corners.

Certain other shaped abrasive particles demonstrated sharpened corner features. For example, the shaped abrasive particles illustrated in FIGs. 6a and 6b defined acute angles between the side surfaces and one of the major surfaces of the particle.

In some instances, each of the particles exhibited surprisingly similar angles at the raised corners. That is, for a single abrasive particle, the angles of all of the corners were substantially similar. However, some particles exhibited different shapes at the corners. For some abrasive particles, different corners on the same abrasive particle had different angles between the top surface and the respective side surfaces.

Other Inherent Features of Note

In addition to the features of the surfaces and edges noted above, certain shaped abrasive grains exhibited openings extending through the volume of the body. As illustrated in FIG. 8, the shaped abrasive particles have openings within the body, and in particular, can even have holes traveling through the entire volume of body.

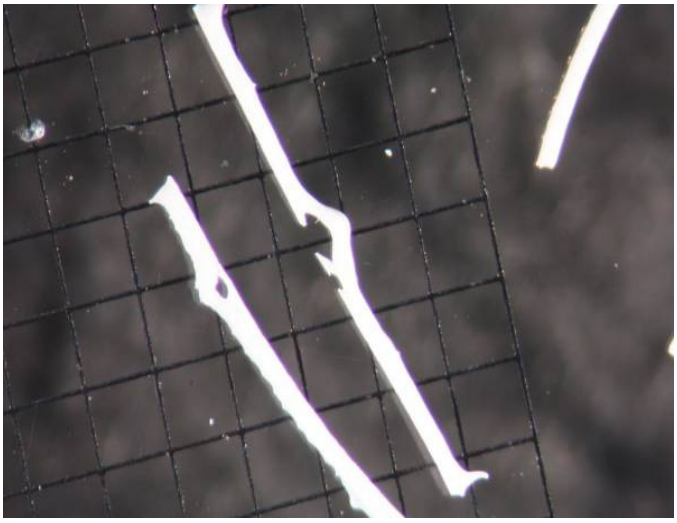

FIG. 8. Shaped abrasive particles having openings.

Conclusion

This examination of historic shaped abrasive particles from the '093 Patent revealed features including *surfaces having convex and concave shapes, raised corners and sharpened edges, surface patterns of grooves and protrusions, particular angles between surfaces, and even holes or openings within the particles*.

For more information regarding screen printing ceramic articles, contact Saint-Gobain Ceramics & Plastics R&D Center, 9 Goddard Road, Northborough, MA or call 508-351- 7755.