

Precisely Shaped Grain (PSG): 3M's Innovation in Abrasive Grain Technology

In 2009, 3M Company introduced two revolutionary coated abrasive products that incorporated the latest technological innovative advancement in ceramic based abrasive grain. The engineered grain was precisely shaped and offered many performance enhancements to the end-user of coated abrasive products. Currently, fibre discs and coated abrasive belt products are available and sold under the 3M™ Cubitron™ II brand. A dramatic step change in metal removal rates, grinding forces and heat reduction have been realized in several customer abrasive applications.

Abrasive Technology Milestones: The need for effective abrasive sanding and grinding (sometimes referred to as *surface modification*) has been around for thousands of years. Centuries of historical abrasive inventions have been documented improving abrasive processes, easing fabrication and surface modifications (see Figure 1 courtesy of 3M Abrasive Systems Division). Abrasive minerals such as emery, flint, garnet, corundum, and diamond are naturally occurring and mined. In 1895, the first large scale synthetic abrasive grit, silicon carbide (SiC) was produced and shortly thereafter aluminum oxide (Al₂O₃). The manufacturing processes of SiC and Al₂O₃ were efficient and the abundance of the formed minerals coupled with the enhanced hardness and toughness made them desirable in abrasive product constructions over the naturally occurring grains. These improved grains quickly became the work horse of the industrial revolution for over 100 years. In 1960, a significant advancement in grain development was unveiled in the manufacturing of aluminum zirconia (AZ) followed by the invention of sol-gel derived ceramic aluminum oxide grains in the 1980's. This latest class of abrasive grain relied on controlling the ceramic body microstructure which improved the crushing behavior of the bulk ceramic. The grain angular sharpness and wear properties were beneficial to the overall abrasive product construction and performance in cut and life. Most recently, 3M introduced the latest breakthrough in the ability to provide a precision shaped ceramic grain and products derived there-from in 2009. The influence of grain geometry is a significant factor in the performance of coated abrasive products. The ability to precisely control this geometry has opened the door to significant performance improvements and will have a tremendous impact on the abrasive industry.

Precision Shaped Grain (PSG): Shown in Figure 2 is a comparative photographic chart of a conventional crushed ceramic grain coated abrasive product construction to that of a precision shaped ceramic grain coated abrasive product construction. The crushed grain is manufactured by conventional crushing and screening techniques producing a grain distribution of particles in both size and sharpness. When coating the crushed grain onto an abrasive backing the result is a distribution of irregular shapes and heights of grain. Conversely, utilization of the PSG yields a desirable, monodisperse and uniform distribution of abrasive grains that are readily available to perform abrasive manipulations on work surfaces.

Understanding the mechanism for metal grinding and chip formation has been one of the keys in fundamentally understanding why PSG products perform at such a high level. Abrasive grinding models, as shown in Figure 3, show that long continuous metal chips, such as those produced in machine tool operations, are the most efficient way to remove metal. Not only are the grinding forces lower, but heat removal from the workpiece travels with the chip. Conventional crushed ceramic grains, because of variations in grain distribution and mineral sharpness, have cutting tips that act as "plows" as they cut through the workpiece material. This is less desirable and reduces the efficiency of the cutting process which causes high frictional force and heat build-up in the substrate. The consistent shape and sharpness of the PSG slices through metal, resulting in more efficient chip formation and metal removal, while greatly reducing heat related part damage and charring.

Observed Product Improvements: The cutting efficiency of the PSG-containing abrasive construction, such as 3M™ Cubitron™ II 984F Abrasive Belts, is one of many product improvements that have been documented. Numerous abrasive application studies within 3M's Customer Abrasive Methods (CAM) Center have generated cut rate curves which compare traditional commercially available Al₂O₃, AZ, and crushed Sol-Gel Ceramic Grain, to that of the innovative PSG containing abrasive belt. In Figure 4, metal removal, expressed as Cut Rate (grams/cycle) is plotted against the number of test cycles. A 2-3 times improvement in grinding efficiency is observed over previous commercially available coated abrasive products. The productivity of PSG products can translate into shorter grinding cycles, faster throughput, and improved product life.

Another desirable aspect of the PSG-containing abrasive constructions is lowering the observed grinding forces during operation. Figure 5 shows technical data, of 3M™ Cubitron™ II 982C Fibre Discs comparing metal removal over five minutes for various commercially available fibre disc products at different grinding forces. For example, the amount of metal removal at a cut of 775 grams/5 minutes of the PSG-containing Fibre Disc takes only 14 pounds of grinding force while that of Competitive Product A requires 20 pounds of grinding force for similar metal removal rate. These added performance advantages of PSG-containing abrasive products can be equated to enhanced worker and end-user ergonomics yielding diminished operator fatigue and higher workpiece throughput.

Customer Case Studies: Numerous end-use customers have reported a tremendous impact to their overall operations utilizing 3M's PSG-containing abrasive products. Figure 6 summarizes a few customer test results obtained from operators. The 3M™ Cubitron™ II 982C Fibre Disc abrasive products are highlighted. Applications were varied and customers typically reported 2-3 times improvement in grinding efficiency, product life, less operator fatigue and lower heat generation on the workpiece. These effects can be observed in product demonstrations at the following You-Tube website:

<http://www.youtube.com/watch?v=U7-xCQklfZc>.

Summary: Abrasive historical advancements have been numerous since the beginning of mankind. 3M's recent discovery and commercialization of abrasive products containing precision shaped abrasive grain represents the latest innovation in abrasive technology. It is changing the cutting efficiency and moving traditional coated abrasives closer to machine tools in metal cutting dynamics. It is impacting many abrasive machining applications in belt and disc applications. It promises to be a transformative platform for many abrasive product constructions for years to come.

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Figure 1: Abrasive Technology Milestones

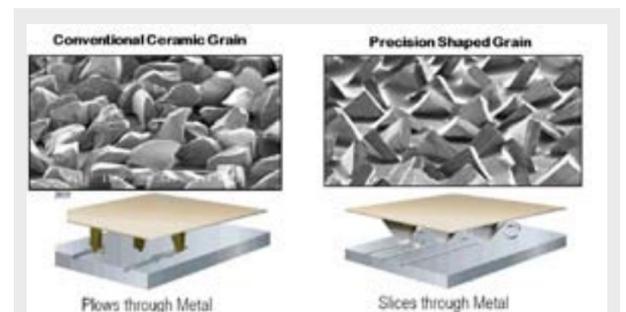


Figure 2: Comparative Chart of Conventional Crushed Ceramic Grains to Precision Shaped Ceramic Grains in a Coated Abrasive Construction

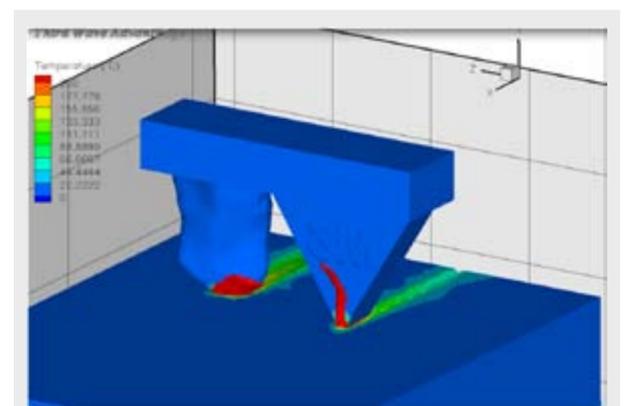


Figure 3: Schematic of Abrasive Grain Plowing vs. Cutting Metal

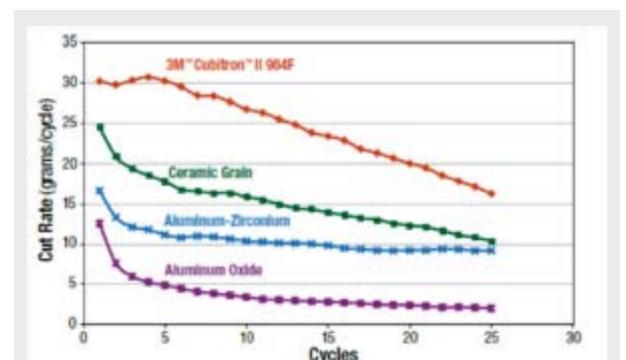


Figure 4: Performance Chart of 3M™ Cubitron™ II 984F Abrasive Belt

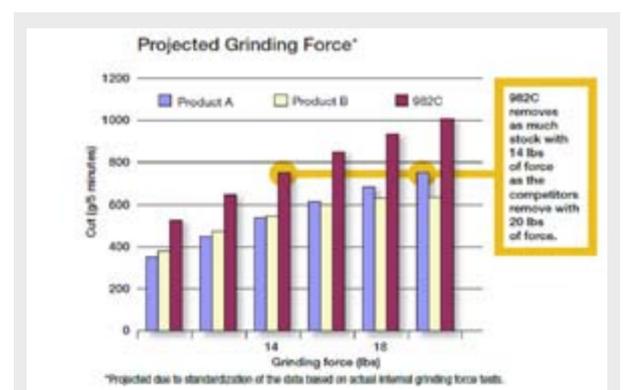


Figure 5: Grinding Force Analysis

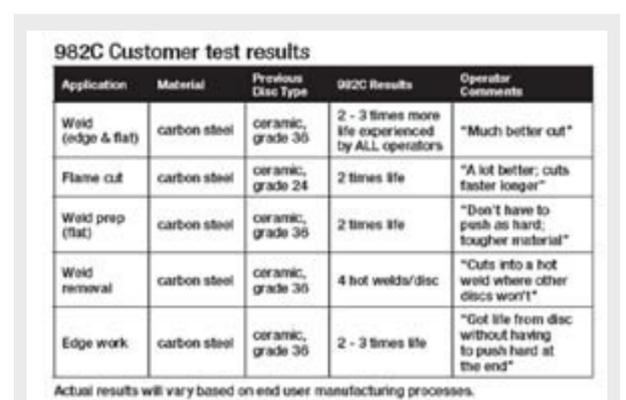


Figure 6: Customer Observations Summary Chart