WHITE PAPER

Enhancing Foundry Safety and Productivity with Superabrasives

NORTON | SAINT-GOBAIN ABRASIVES

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Casting is a near net shape process requiring much less metal removal compared to machining from stock material. However, the sprues, runners, risers and gates used to feed molten metal in the mold and allow air or gases to escape require removal and finishing. The cleaning and finishing rooms in a foundry are typically responsible for removing investment, sand or ceramic mold materials, cutting-off and fettling of sprues and gates, deburring edges and parting lines, removing defects and blending repairs. Since cast materials are often harder and contain more alloys compared to wrought alloys, abrasives are preferred for cutting, grinding and finishing cast alloys. Gate removal and blending is typically a hot, dirty process and foundries are having a difficult time finding workers willing to do the monotonous, heavy and dangerous work of finishing castings with hefty grinders.

Figure 1. Foundry workers pouring molten metal into molds. Source: OSHA

While a low carbon steel like AISI 1020 has 0.2% carbon nominally, cast iron alloys contain 1.7 to 4% carbon, resulting in a mixture of pearlite (alpha ferrite and iron carbide) containing particles of carbon in the form of graphite flakes. The dispersed graphite flakes produce cast iron's excellent damping characteristics. The graphite flakes also enhance machinability and grindability because they allow the chips to easily break, which reduces loading. Gray cast iron alloys have additions of silicon to refine the size of graphite flakes, which improves strength and reduces machinability. The faster cooling or chilling of iron at the mold surface can produce difficult-to-grind hard carbides instead of graphite. Gray cast iron is used to make engine blocks, machine tool bases, cookware, pipe, pump housings and even permanent molds for casting aluminum, zinc and copper alloys.

Nodular or ductile iron utilizes alloying additions of magnesium, sodium, cerium or calcium to precipitate the graphite in the form of spheres or nodules instead of flakes. Ductile iron is also called spheroidal graphite (SG) iron. Ductile iron alloys have better mechanical properties such as ductility (percent elongation) and yield strength. The absence of graphite flakes reduces damping ability and makes ductile iron more difficult to machine and grind. As federal, state and municipal governments are beautifying their building and cityscapes with ornamental cast iron street lights, decorative railings and fencing, ornate manhole covers and grates, demand for cast and ductile iron increases.

White cast irons are made by slowly cooling an alloy with lower levels of silicon, resulting in a very hard, brittle alloy consisting of iron carbide (cementite) particles in a pearlite matrix. White cast iron is suitable for mill rolls, drawing dies, extrusion nozzles and other parts requiring high wear resistance. An annealing heat treatment of white cast iron converts the iron carbide particles into graphite, resulting in a malleable cast iron alloy with improved ductility and machinability. Certain grades of white and malleable cast iron are even hardenable. The high hardness of white cast irons makes the alloy extremely difficult to machine and grind.

Cast iron alloys have many applications beyond ornamental and architectural elements. Many automotive manufacturers have switched from aluminum blocks back to cast iron blocks and heads made from an advanced form of cast iron called vermicular, or compacted graphite iron (CGI). CGI is especially desirable in diesel and racing engines because the higher tensile and fatigue strength of CGI can better handle the higher pressures, allowing thinner walls, which results in 20% lighter engine weight overall. The tensile strength of CGI is 80% higher than gray cast iron. CGI also has 40% higher stiffness, twice the fatigue strength and improved castability compared to gray cast iron. CGI is also used to make brake discs and exhaust manifolds. The interconnected worm-shaped graphite in CGI makes it more difficult to machine compared to gray cast iron.

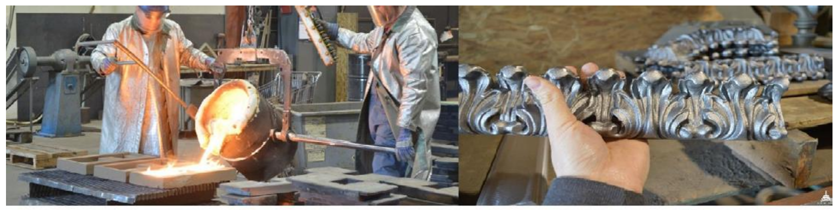

Figure 2. (a) Salt Lake City foundry workers pouring ornamental cast iron to repair more than 1,300 cracks in the U.S. Capitol Dome. (b) Example of a newly cast lambs' tongue ornament. Source: Architect of the Capitol AOC.gov

Trends in the foundry finishing room

Many OEMs have been disappointed in the quality of castings produced overseas and are reshoring or returning to domestic foundries. The foundry industry is experiencing a continued trend toward modernization and automation of their finishing rooms to handle the increased demand and to encourage additional onshoring of components. Increased use of computerized numerical control (CNC) machines and robots improves productivity and finishing consistency. In some cases, automation can allow a single operator to operate multiple machines. Automation also helps fill the "skills gap" as trained workers are becoming difficult to find. The newer jobs in modern foundries are less labor intensive and require higher skilled workers with advanced training.

Newer entry-level CNC machines designed for automated grinding of smaller castings are selling for around $250,000. The robotic finishing machines can also provide handling, picking, feeding, part transfer, packing and palleting capabilities. Inspection and vision system options can ensure finish consistency and quality.

Figure 3. Cutting and fettling with conventional abrasives in foundry metal gate removal applications generates hot metal swarf, odors, dust and flying debris. Source: Norton/Saint-Gobain Abrasives

Risk Factors Causing Musculoskeletal and Other Injuries in Foundries
Being Exposed To Vibrating Tools And Work Surfaces
Bending And Twist of Hands, Forearms And Arms
Coming In Contact With Sharp Edges And Rapidly Moving Abrasive Surfaces
Doing The Same Or Similar Tasks Repetitively
Exerting High Levels Of Force To Handle Or Move Materials
Exposure To Airborne Dust And Flying Debris
Fatigue And Dehydration From Exposure To Heat
Maintaining Static (I.E. Nonmoving) Body Postures For Long Periods
Monotonous Manual Pushing And Pulling
Poor Gripping Surfaces Require High Contact Stress To Hold Tools Or Part Securely
Working In Awkward Postures Or Reaching Long Distances

Figure 4. Musculoskeletal and other injury risk factors in foundries.
Data source: OSHA

Another trend in the foundry industry includes enhancements to the workplace to meet environmental, safety and health (EHS) concerns such as the removal or minimization of dust (especially crystalline silica), improved ergonomics and the elimination of difficult tasks for humans. OSHA and the foundry industry are proactively improving ergonomics to reduce injuries (Solutions for the Prevention of Musculoskeletal Injuries in Foundries or Ergonomics in Foundries). Robots can take on tasks difficult for operators, which might cause musculoskeletal injuries. Foundries have been making changes in manufacturing processes to comply with OSHA's newer silica regulations: Occupational Exposure to Respirable Crystalline Silica OSHA 2016 Rule. Automation also moves operators further from the work area and from potential safety hazards such as airborne dust, flying debris and hot metal. The organic resins in conventional abrasives can generate noxious odors during grinding. Improving foundry workplace conditions helps attract and keep skilled workers and improves employee morale and allows them to focus on tasks.

Superabrasive advantages in foundry applications

The trend toward automaton of cut-off and finishing operations in the foundry is generating the need for advanced abrasives with higher consistency, longer life and improved performance. Superabrasives meet all of these requirements. Superabrasive wheels consist of diamond or cubic boron nitride (cBN) abrasive grains attached to a steel wheel with a resin, vitrified metal or electroplated (EP) bond. Superabrasive products are available in a variety of forms including cut-off wheels, snagging wheels and superabrasive burrs. Specifically, custom wheel sizes and shapes are available on a made-to-order basis to enable robotic programmers to design automated grinding systems with wider range of motions or paths.

Figure 5. Norton Winter conventional nickel electroplated (EP) metal single layer diamond superabrasive wheels for fettling. Source: Norton/ Saint-Gobain Abrasives

Since much of the finishing has traditionally been done manually or offhand, most of the cutting and grinding is "dry" or done without coolants to remove the intense heat generated at the abrasive workpiece interface. Abrasives with durable, heat resistant bonds are highly desirable for foundry applications. The new diamond based superabrasive technology Ironclad™ by

Norton | Saint-Gobain utilizes an advanced heat resistant bond technology. This new and improved heat resistance dramatically reduces the oxidation of the bond at high temperatures, which increases the life of these products through better grit retention. The bond also has better lubricity compared to other superabrasive products on the market today.

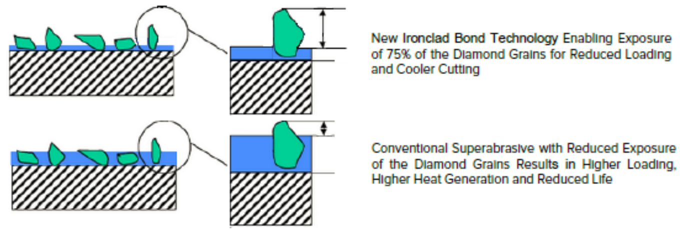

Figure 6. Improved superabrasives with Ironclad™ high integrity, oxidation resistant bond technology enabling high grain exposure compared to conventional superabrasives. Source: Norton/Saint-Gobain Abrasives

Better cutting action is also a feature of the new Ironclad technology with up to 75% of the grain exposed. The high integrity and oxidation resistant bond in Ironclad products enables high levels of grain exposure. The increased grain exposure provides more clearance between grains, resulting in reduced loading and better removal of swarf or metal chips, which reduces heat generation and workpiece damage. Loading of an abrasive surface occurs more frequently with limited grain exposure. Metal loading results in metal-to-metal wear and high heat generation. Overheating of normal superabrasive wheels can cause grain bonds to fail and release or cause premature dulling of the superabrasive grits. The cooler cutting temperatures of the Ironclad wheels significantly reduce metallurgical damage (heat check) and burn (blue discoloration), resulting in higher quality parts that retain their metallurgical integrity and fewer or no rejected parts.

Ironclad superabrasive wheels have several important performance benefits for enabling CNC and robotic automation which foundries are increasingly moving toward. First, the longer life and consistent cutting and grinding ability reduces downtime for wheel changes and setup. Additionally, it provides predictable grinding and minimal wear through the life of the product — the outer diameter of the wheel does not change. Automation is simpler with the new single layer superabrasives because the programmer does not have to compensate for wheel wear. This ultra-low wheel wear feature also keeps down the costs of new CNC grinders, which do not need special lasers to find and define the location of the wheel and workpiece after each grind.

CNCs work best with a product that does not change diametrically during the grinding process because the wheel location is known. The harder thing to deal with in this case is changes in the dimensions of the incoming workpiece casting. Unlike conventional grinding wheels, Ironclad wheels require infrequent replacement and there is no need to dress wheels because they stay sharp throughout their lifetime. The rigid steel hub on the wheels provides mechanical reinforcement to enhance stiffness and stability, reduce vibration and eliminate the risk of wheel breakage. The superabrasive wheels are balanced with G2.5-level precision. The reduced vibration improves machine spindle lifetimes and helps with ergonomics in offhand manual grinding applications. The absence of diameter changes high precision balance and lower vibration levels improves accuracy and control in automated CNC and robotic cells. The steel hub also enables higher operational surface speeds up to 100 meters per second, which can enable full utilization of the superabrasive in some applications.

Superabrasive cut-off and fettling products also provide safety and ergonomic benefits and they are lighter and easier to handle. The danger of wheel breakage is eliminated by the steel hub. Superabrasives are cooler cutting compared to conventional abrasives, so the risk of operator burns from hot workpieces is reduced. Cutting or grinding is easier because the new superabrasive wheels stay sharper longer and load less,so operators do not have to apply as much manual pressure. Repetitive tasks, heavy workpieces and dangerous work can be handed off to a robotic or CNC grinder.

There is also significantly less dust and odors generated with superabrasives. Conventional grinding wheels generate 10 times the amount of dust compared to superabrasive wheels. Superabrasive wheels do not contain any resins, silica alumina or silicon carbide so the chance of creating airborne respiratory hazards is minimized. Superabrasives also reduce recycling and waste disposal costs because alumina silicon carbide, and organics are not added to the waste stream.

Norton Winter superabrasive cut-off, snagging and burrs have shown promising results in many foundry field tests. Superabrasives far exceed conventional abrasives in abrasive cost per part and cycle time performance. The advanced superabrasives have demonstrated up to 20 times life improvement compared to conventional abrasives. In comparison to competitive superabrasive wheels, Ironclad superabrasive wheels grind up to 75% more nodular cast iron parts compared to normal plated superabrasive wheels, which resulted in a 49% savings on abrasive consumption and a 20% total cost reduction. Superabrasive burrs are even replacing carbide burrs for finishing and deburring hard-to-reach areas and holes. While the new superabrasive wheels may have a higher initial cost, the total abrasive cost per piece is significantly lower.

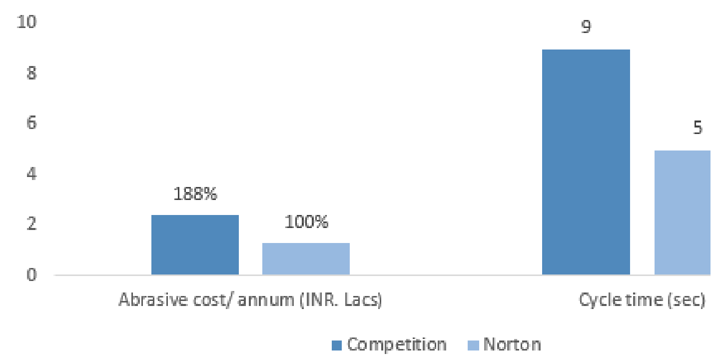

Figure 7. In a case study on ductile iron castings, superabrasives outperformed conventional abrasives on both cost per part and cycle time factors. Source: Norton/Saint-Gobain Abrasives

Next steps/conclusion

The high strength, heat resistant and durable bond of new Ironclad superabrasive wheels allow exposure of 75% of the diamond grains, resulting in enhanced metal removal performance, retention of part metallurgical integrity and extended abrasive life in cut-off, fettling, deburring and snag grinding of casting gates, parting lines, sprues and runners. The enhancements in parts per wheel, wheel consistency or minimal wear throughout the wheel's life, reduced vibration characteristics and improved balance are enabling factors for CNC and robotics automation efforts. Ironclad wheels promise vast improvement in

Figure 8. Norton Winter Ironclad superabrasive foundry wheels. Source: Norton/ Saint-Gobain Abrasives

production rates and higher ROI compared to conventional bonded products. While Norton | Saint-Gobain Abrasives is currently field testing at customer sites, the new superabrasive wheels and burrs will be available starting in January 2020.

Casting engineers and workers interested in evaluating the new superabrasives in their foundries can visit www.nortonabrasives.com or contact their local Norton sales rep for more information. Additional literature is available on the website.

ABOUT NORTON

For over 110 years, Norton has provided innovative bonded, coated and super abrasive products and solutions for the industrial marketplace. Now as a member of the Saint-Gobain Abrasives family of world class brands, Norton is the leading full line supplier of the most advanced abrasives for metal and woodworking, automotive, aerospace, cutting tool, bearing, glass, sporting goods, foundry, welding, medical, electronics and any other market where grinding is performed. Whether you're sanding furniture, finishing a turbine blade or slicing a semiconductor component, if you are using abrasives, Norton offers the industry's widest range of high performance to value price abrasive products and the application know-how to meet your needs. They are the world's leading supplier of bonded abrasives, with more than 250,000 types and sizes, most custom-designed and engineered for specific applications. They are also a leading manufacturer of coated abrasive products, offering more than 38,000 types of coated products with a variety of abrasive grains and backings. Norton's Bear-Tex surface finishing line of non-woven nylon products includes hand pads, rolls, discs, wheels and belts.