NORTON
SAINT-GOBAIN

Transforming surfaces ...and beyond

FINISHING 3D PRINTED PARTS APPLICATION GUIDE

3D printing (3DP) or additive manufacturing (AM) which started as an emerging technology has now grown to commercial production for many industries, such as aerospace, medical, tooling, automotive and energy. With the exponential adoption of 3D printing, particularly with metal materials, finishing has been a key challenge. Many 3D printed parts require additional finishing steps to improve dimensional tolerance and surface quality.

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SAINT-GOBAIN

This application guide is designed to provide recommendations for the best abrasive products for each application. The full range of product availability can be found at www.nortonabrasives.com. Products listed in this guide are hyperlinked to our website for your convenience. Please contact your Norton representative with any questions or for additional products, sizes and configurations.

INTRODUCTION

The thermal-mechanical properties of materials, such as hardness and ductility, play a significant role in the selection of material types for metal 3D printing applications. Material properties are also an important factor for choosing the correct finishing processes and abrasive products. Among typical 3D printed metals, superalloys and steels are generally finished with ceramic or cBN abrasives, while titanium and aluminum are finished with silicon carbide or diamond abrasives.

In addition to material properties, part geometry, initial surface condition, requirements for dimensional tolerance and surface finish are other factors to consider. 3D printed parts often consist of various complex features, and therefore may require different types of abrasive tools to achieve desired surface finish and optimal operation efficiency. Norton | Saint-Gobain Abrasives, offers a comprehensive line of abrasive solutions for finishing 3D printed metal parts. This application guide is designed to help recommend Norton products based on part geometry, material removal and finish needs.

First Steps

One of the first steps in the process of finishing additively manufactured parts is removing the printed part from the build plate and/or removing the support structures. There are several Norton products which can be used to complete this task including products for both manual and CNC operations. For manual cut-off, Norton's free-cutting and user-friendly thin wheels can be paired with a right angle grinder. For automated and high precision applications we offer superabrasive diamond or cBN cut-off wheels.

Manual Cut-Off

Machine: Portable Cut-Off Tool
Small Diameter Cut-off Wheels <4"

Norton Gemini Free Cut Aluminum Oxide
- All purpose

Norton BlueFire Zirconia Alumina / A/O Blend
- For harder to cut materials and applications

Machine: Right Angle Grinder
Right Angle Grinder Cut-Off Wheels >4" Diameter

Norton Quantum3 Ceramic Alumina
- For thicker parts and harder to grind materials

Norton Gemini RightCut Aluminum Oxide
- All purpose

Norton Gemini ALU Aluminum Oxide
- For use on aluminum or soft metals

Automated or CNC Cut-Off

MATERIAL:	Ferrous cBN cut-off wheels for automated cut-off of ferrous materials	
SIZE:	Less than 14" OD	Greater than 14" OD
SUGGESTED SPECIFICATION:	CB100-TB99E-1/4	CB80-TBB-5/16

MATERIAL:	Non-Ferrous Diamond cut-off wheels for automated cut-off of non-ferrous materials	
SIZE:	Less than 14" OD	Greater than 14" OD
SUGGESTED SPECIFICATION:	SD80-R100B99E-1/4	SD80-R100B69-5/16

For additional specifications and sizes contact your Norton Representative.

Next Steps

After the part has been cut-off and removed from the build plate, the plate must be prepared for reuse. Rotary or reciprocating surface grinding can be used to re-establish the required roughness, flatness, and parallelism of metal build plates. Norton surface grinding wheels using ceramic alumina abrasive grain are recommended to achieve a consistent surface finish, with lower cycle time and longer wheel life.

Toolroom/Surface Grinding Wheels

MACHINE: Surface Grinding Machine

BRAND: Norton Quantum Ceramic Toolroom Grinding Wheels

SIZE	SPECIFICATION	PART #
8 x ½ x 1-1/4	5NQ 60 JVS	662533**87214**
12 x 1-1/2 x 5	5NQ 60 JVS	690831**59118**

Surface Grinding Segments

MACHINE: Blanchard Style Rotary Surface Grinding Machine

BRAND: Norton Quantum Surface Grinding Segments

SUGGESTED SPECIFICATIONS: Stainless: 38A46-E12VBEP
Steels/Others: 86A46-F12VBEP

For additional specifications and sizes contact your Norton Representative.

Using Off-Hand Tools

Free form finishing using off-hand tools can provide an excellent finish for metal 3D printed parts. A wide range of abrasive products is available including discs, belts and mounted point wheels which can be used for off-hand or robotic grinding. Ceramic abrasives are recommended for use on stainless steel and superalloys while Silicon Carbide or Zirconia abrasives are best for finishing titanium and aluminum.

The abrasive products shown in this section can be used with portable power tools, including mini right angle sanders, die grinders or file belt grinders. The light weight, small size and good flexibility of these portable tools allows for many possibilities in the finishing process, such as bringing tools to stationary parts, bringing parts to tools, and simultaneously manipulating both tools and parts. Multiple abrasive tools can be set up on a workstation to finish a variety of complex features with the most effective tools.

TOOL	GRINDING Material Removal	BLENDING Defect Removal	FINISHING Final Finish
MINI ANGLE SANDER 	COATED QUICK-CHANGE DISCS 60/80 Grit	NON-WOVEN QUICK-CHANGE DISCS Coarse Grit	NON-WOVEN QUICK-CHANGE DISCS Medium or Fine Grit

MINI ANGLE SANDER RECOMMENDATIONS

Grinding – Material Removal

Coated Quick-Change Discs

Norton Blaze F980 Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton R422 Silicon Carbide
- For use on Aluminum

Blending – Defect Removal

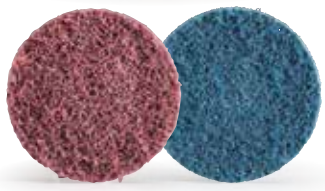
Non-Woven Quick-Change Discs - Coarse Grit

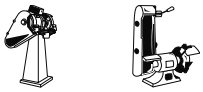
Norton Rapid Prep Aluminum Oxide

Finishing – Final Finishing

Non-Woven Quick-Change Discs - Medium or Fine Grit

Norton Rapid Prep Aluminum Oxide



TOOL	GRINDING Material Removal	BLENDING Defect Removal	FINISHING Final Finish
ORBITAL SANDER 		LIGHTWEIGHT PAPER DISCS	
IN-LINE DRUM SANDER 	COATED PORTABLE BELTS 36 to 120 grit	NON-WOVEN PORTABLE BELTS Coarse Grit	NON-WOVEN PORTABLE BELTS Medium or Fine Grit
OFF-HAND BENCHSTAND AND BACKSTAND 	COATED BENCHSTAND AND BACKSTAND BELTS ENGINEERED ABRASIVE BELTS	NON-WOVEN BENCHSTAND AND BACKSTAND BELTS Coarse Grit ENGINEERED ABRASIVE BELTS	NON-WOVEN BENCHSTAND AND BACKSTAND BELTS Medium or Fine Grit ENGINEERED ABRASIVE BELTS

ORBITAL SANDER RECOMMENDATIONS

Blending – Defect Removal

Lightweight Paper Discs

Norton Drylce A975 No-Fil Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton A275OP No-Fil Aluminum Oxide
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton Durite A475 No-Fil Silicon Carbide
- For use on Titanium and Aluminum

PNEUMATIC IN-LINE DRUM SANDER RECOMMENDATIONS

Grinding – Material Removal

Coated Abrasive Portable Belts

Norton RedHeat R983 Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton BlueFire R823P Zirconia Alumina
- For use on Aluminum

PNEUMATIC IN-LINE DRUM SANDER RECOMMENDATIONS

Blending – Defect Removal
Finishing – Final Finishing

Non-Woven Portable Belts

Norton Vortex Rapid Prep Engineered A/O
- Coarse grit for scratch removal and medium or fine grit for final finishing
- Premium grain and proprietary "CLEAN BOND" for smear-free finish on Aluminum, Inconel, Stainless Steels, Titanium and Superalloys

OFF-HAND BENCHSTAND AND BACKSTAND RECOMMENDATIONS

Grinding – Material Removal

Coated Abrasive Benchstand and Backstand Belts

Norton Blaze R980P Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton RedHeat R983 Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton Bluefire R823P/R884P Zirconia Alumina
- For use on Aluminum

Material Removal, Blending and Finishing

Engineered Abrasive Belts

Norton NORAX U243 J-Weight
- Available in X80 to X16 for all material types

Norton NORAX U464 X-Weight
- Available in X110 to X70 for Titanium

Norton NORAX U936 W-Weight
- Available in X200 to X5 for all material types

Blending – Defect Removal
Finishing – Final Finishing

Non-Woven Benchstand and Backstand Belts

Norton Vortex Rapid Prep Engineered A/O
- Coarse grit for scratch removal and medium or fine grit for final finishing
- Premium grain and proprietary "CLEAN BOND" for smear-free finish on Aluminum, Inconel, Stainless Steels, Titanium and Superalloys

CONTOUR SURFACE WITH OPEN ACCESS

TOOL	GRINDING Material Removal	BLENDING Defect Removal	FINISHING Final Finish
DIE GRINDER 	MOUNTED FLAP WHEELS Coarse Grit	NON-WOVEN INTERLEAF FLAP WHEELS	NON-WOVEN FLAP WHEELS
MINI ANGLE SANDER 	NON-WOVEN QUICK-CHANGE DISCS Coarse Grit	NON-WOVEN QUICK-CHANGE DISCS Medium Grit	NON-WOVEN QUICK-CHANGE DISCS Medium or Fine Grit
PEDESTAL GRINDER 	ARBOR HOLE FLAP WHEELS Coarse Grit	ARBOR HOLE NON-WOVEN INTERLEAF FLAP WHEELS Coarse Grit	ARBOR HOLE NON-WOVEN FLAP WHEELS Medium or Fine Grit

DIE GRINDER RECOMMENDATIONS

Use blending products directly on 3D printed parts if minimal shape change is desired on intricate features

Grinding – Material Removal

Coated Abrasive Flap Wheels - Coarse Grit

Norton Blaze R920 Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton R207 Aluminum Oxide
- For use on Aluminum

Blending – Defect Removal

Non-Woven Interleaf Flap Wheels - Medium Grit

Norton Non-Woven Interleaf Flap Wheels Aluminum Oxide

Finishing – Final Finish

Non-Woven Flap Wheels - Medium or Fine Grit

Norton Non-Woven Flap Wheels Aluminum Oxide

MINI ANGLE SANDER RECOMMENDATIONS

Non-Woven Quick-change discs made of tough and yet flexible synthetic fiber mesh for medium to light pressure grinding and finishing. Works well on all metals.

Grinding – Material Removal

Non-Woven Quick-Change Discs - Coarse Grit

Norton Rapid Prep XHD Ceramic Alumina

Blending – Defect Removal

Non-Woven Quick-Change Discs - Medium Grit

Norton Vortex Rapid Blend Engineered A/O

Finishing – Final Finish

Non-Woven Quick-Change Discs - Medium or Fine Grit

Norton Rapid Blend Aluminum Oxide

PEDESTAL GRINDER RECOMMENDATIONS

Flap wheels are ideal for intricate shapes and contours thanks to good conformity of design

Grinding – Material Removal

Arbor Hole Coated Flap Wheels - Coarse Grit

Norton Blaze R920 Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

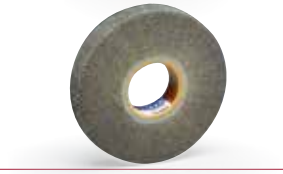
Norton R369 Aluminum Oxide
- For use on Aluminum

Norton R207 Aluminum Oxide
- For use on Aluminum

Blending – Defect Removal

Arbor Hole Non-Woven Interleaf Flap Wheels - Coarse Grit

Norton Non-Woven Interleaf Flap Wheels Aluminum Oxide



Finishing – Final Finish

Arbor Hole Non-Woven Flap Wheels - Medium or Fine Grit

Norton Non-Woven Flap Wheels Aluminum Oxide

CONTOUR SURFACE WITH LIMITED ACCESS

TOOL	GRINDING Material Removal	BLENDING Defect Removal	FINISHING Final Finish
FILE BELT MACHINE 	COATED FILE BELTS 60/80 grit	NON-WOVEN FILE BELTS Coarse Grit	NON-WOVEN FILE BELTS Medium or Fine Grit

FILE BELT RECOMMENDATIONS

Grinding – Material Removal

Coated File Belts

Norton Blaze R980P Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton Bluefire R887D/R823P Zirconia Alumina
- For use on Aluminum

Blending – Defect Removal

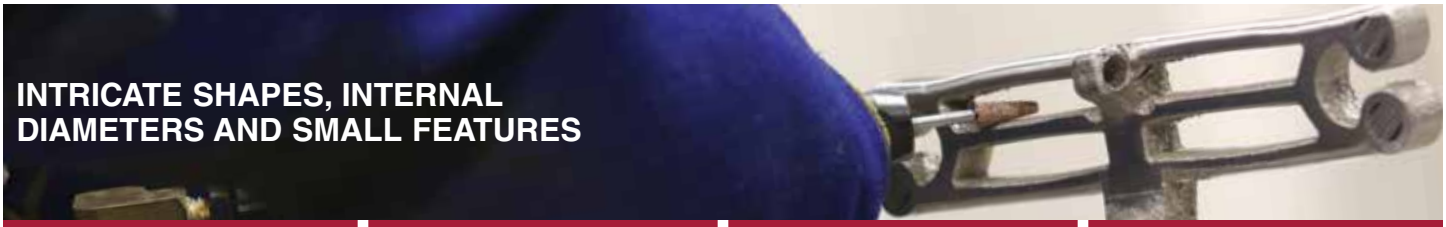
Non-Woven File Belts - Coarse Grit

Norton Rapid Prep Aluminum Oxide

Finishing – Final Finish

Non-Woven File Belts - Medium or Fine Grit

Norton Rapid Prep Aluminum Oxide



TOOL	GRINDING Material Removal	BLENDING Defect Removal	FINISHING Final Finish
DIE GRINDER 	CARTRIDGE ROLL	NON-WOVEN CROSS BUFF	NON-WOVEN UNIFIED WHEEL
	SLOTTED DISC	BORE POLISHER	NON-WOVEN STAR
	MOUNTED POINT WHEEL Coarse Grit	MOUNTED POINT WHEEL Fine Grit	COTTON FIBER MOUNTED POINT

DIE GRINDER RECOMMENDATIONS

Use blending products directly on 3D printed parts if minimal shape change is desired on intricate features

Grinding – Material Removal

Cartridge Rolls

Norton Blaze R920 Ceramic Alumina
- For aggressive material removal

Overlap Slotted Discs

Norton Blaze R920 Ceramic Alumina

Mounted Point Wheels - Coarse Grit

Norton Norzon Zirconia Alumina - Resin Bond
- For long tool life

Blending – Defect Removal

Non-Woven Cross Buffs

Norton Non-Woven Cross Buff Aluminum Oxide

Bore Polishers

Norton Bore Polisher Aluminum Oxide

Mounted Point Wheels - Fine Grit

Norton Norzon Zirconia Alumina - Resin Bond

Finishing – Final Finish

Non-Woven Unified Wheels

Norton Rapid Blend NEX Unified Wheel Aluminum Oxide

Non-Woven Stars

Norton Surface Preparation Star Aluminum Oxide

Cotton Fiber Mounted Points

Norton Cotton Fiber Aluminum Oxide - Resin Bond

EDGE AND CHAMFER

TOOL	GRINDING Material Removal	BLENDING Defect Removal	FINISHING Final Finish
MINI ANGLE SANDER 	COATED QUICK-CHANGE DISC	NON-WOVEN QUICK-CHANGE DISC Medium Grit	NON-WOVEN QUICK-CHANGE DISC Medium or Fine Grit
DIE GRINDER 	CARTRIDGE ROLL CARBIDE BURRR	NON-WOVEN CROSS BUFF MOUNTED POINT WHEEL	NON-WOVEN UNIFIED WHEEL COTTON FIBER MOUNTED POINT
PEDESTAL GRINDER 		NON-WOVEN CONVOLUTE WHEEL	ABRASIVE BUFFING WHEEL

MINI ANGLE SANDER RECOMMENDATIONS

Quick-Change discs recommended for deburring and chamfer finishing of external large areas.

Grinding – Material Removal

Coated Quick-Change Discs

Norton Blaze F980 Ceramic Alumina
- For use on Inconel, Stainless Steels, Titanium and Superalloys

Norton R422 Silicon Carbide
- For use on Aluminum

Blending – Defect Removal

Non-Woven Quick-Change Discs - Medium Grit

Norton Vortex Rapid Blend Engineered A/O

Finishing – Final Finish

Non-Woven Quick-Change Discs - Medium or Fine Grit

Norton Rapid Blend Aluminum Oxide

DIE GRINDER RECOMMENDATIONS

For intricate features and difficult to reach areas

Grinding – Material Removal

Cartridge Rolls

Norton Blaze R920 Ceramic Alumina

Carbide Burrs

Norton Double Cut Carbide Burr

Blending – Defect Removal

Non-Woven Cross Buffs

Norton Non-Woven Cross Buffs Aluminum Oxide

Mounted Point Wheels

Norton Norzon Zirconia Alumina - Resin Bond

Finishing – Final Finish

Non-Woven Unified Wheels

Norton Rapid Blend NEX Unified Wheel Aluminum Oxide

Cotton Fiber Mounted Points

Norton Cotton Fiber Aluminum Oxide - Resin Bond

PEDESTAL GRINDER RECOMMENDATIONS

Blending – Defect Removal

Non-Woven Convolute Wheels

Norton Rapid Finish General Purpose A/O & S/C

Finishing – Final Finish

Buffing Wheels

Norton FAB (Fixed Abrasive Buff) Wheel

- Buffing wheel with abrasive grain on both sides of the cloth
  Virtually eliminates the need for messy compound

CNC GRINDING

CNC grinding of 3D printed parts can be performed using conventional bonded or superabrasive mounted points as well as larger wheels. Norton offers a wide selection of products using a variety of shapes, grains, and bond technologies in both stock and made-to-order products. CNC grinding for large batch processes would typically be performed with larger wheels while CNC grinding with conventional bonded or superabrasive mounted points can be used for more flexibility on detailed parts.

CNC GRINDING FOR LARGE BATCH PROCESS

- Grinding wheels can be prepared using a form roll dresser which matches part profile for Creepfeed, surface or ID/OD plunge grinding.
- Part profile can also be produced by CNC grinding on multi-axis machines.
- Tight control of profile accuracy and surface finish is ensured with proper selection of wheel specification, grinding process and wheel dressing
- Grinding wheels and customized process solutions are available for Ni-based superalloys, titanium, tool steels, Co-Cr alloys, stainless steel, and composite materials

Norton Vitrium3 Bond with Ceramic Alumina

- Precision grinding with cooler cutting

Norton Winter Vitron7 Vit cBN Superabrasive Wheels

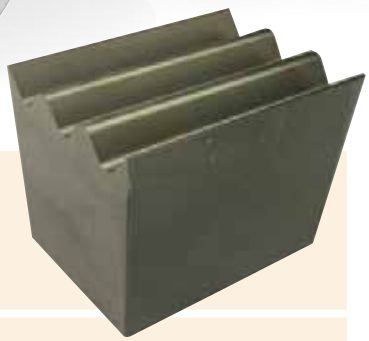
- For high production volumes

Norton Winter Paradigm Diamond Superabrasive Wheels

- For difficult-to-grind materials

Norton Winter Electroplated Diamond or cBN Superabrasive Wheels

- For smaller lot sizes and added flexibility

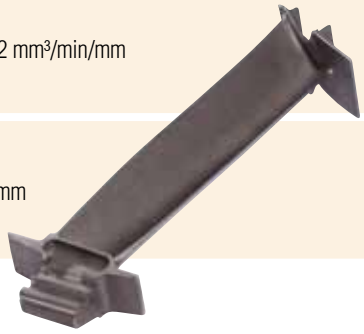


Case Study

PARTS:	3D printed Inconel 718 and Ti-64Al-4V with profile shown. All parts were treated by stress relief, hot isostatic press, anneal and age hardening before grinding
MACHINE:	Creepfeed grinder with 5-10% water soluble coolant
DRESSER:	Form plunge roller

NORTON PRODUCT:	Vitrium3 wheel with Quantum ceramic abrasives for Inconel 718,
RESULT:	• Surface finish of ~0.7 um achieved for Inconel 718, at specific material removal rate of approximately 2 mm^3/min/mm • Desirable compressive residual stress on the ground surface

NORTON PRODUCT:	Paradigm wheel with diamond abrasives for Ti-64Al-4V
RESULT:	• Surface finish ~ 0.9 um for Ti-64Al-4V, at specific material removal rate of approximately 2 mm^3/min/mm • Desirable compressive residual stress on the ground surface



FLEXIBLE CNC GRINDING WITH MOUNTED POINT WHEELS

- Used on jig grinders, machining centers and CNC milling machines in a way similar to CNC machining with end mills
- Available in a wide variety of forms, sizes, abrasives and bond technologies
- Can be custom made to match part geometry

Norton Quantum Ceramic Alumina – Vitrified Bond

- Vitrified bond wheels for long wheel life

Norton Charger Z/A A/O Blend – Resin Bond

- Resin bond wheels for fast stock removal, and dry grinding when coolant is not possible

Norton Winter cBN Mounted Points

- cBN grains for long wheel life on difficult-to-machine materials

Norton Winter Electroplated Mounted Points

- Electroplated wheels for easy usage without dressing

Case Study

PARTS:	3D printed Inconel 718 with curved chamfer and curved surface shown. All parts were treated by stress relief before grinding
MACHINE:	5-axis CNC machine with 5% water soluble coolant
NORTON PRODUCT:	Electroplated wheels with 100 grit cBN grains
RESULT:	• Surface finish of ~1.2 um and feed rate of 150 mm/min achieved • Expected wheel life > 50 meters of grinding length or over 300 minutes of grinding time

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