NORTON®
SAINT-GOBAIN

SOLUTIONS FOR
GEAR GRINDING

GEAR GRINDING

Grinding wheels are used to generate the profile of the gear teeth. The machine and gear type determine the shape of the grinding wheel. Continuous gear generation, profile grinding and bevel gear grinding are the most common grinding processes.

TM

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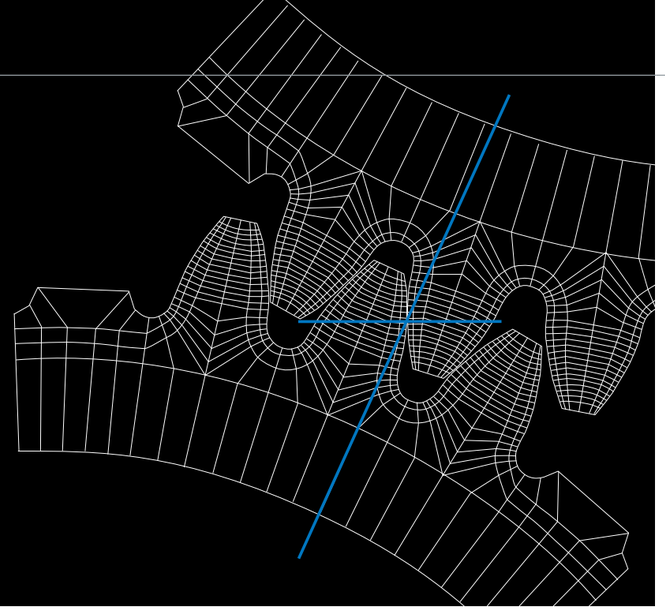
INTRODUCTION

Increasingly stringent requirements for gears result in tighter tolerances, higher profile accuracy and improved surface finish. The choice of abrasive is key in the production of high quality gears. In order to select the right abrasive, it is important to understand the terminology and technical criteria.



DEFINITIONS:

Line of action: line along which the force between two meshing gear teeth is directed.

Pitch point: the point where the line of action crosses a line joining the two gear centers.

Pitch circle: the circle centered on the gear axis and passing through the pitch point.

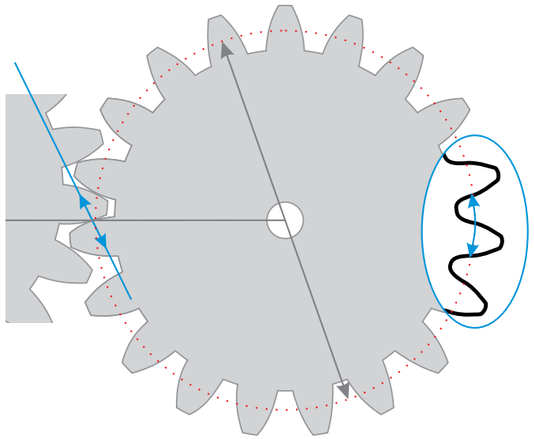
Circular pitch (P): the distance from one face of a tooth to the corresponding face of an adjacent tooth on the same gear, measured along the pitch circle.

Pitch diameter or reference diameter (D): diameter of a pitch circle.

Modulus or "size coefficient" (M): the module of a gear is equal to the pitch diameter divided by the number of teeth Z. Pressure angle (a): the angle at a pitch point between the line of action which is normal to the tooth surface, and the plane tangent to the pitch surface.

Profile angle (V): the angle at a specified pitch point between a line tangent to a tooth surface and the line normal to the pitch surface (which is a radial line of a pitch circle).

LINE OF ACTION



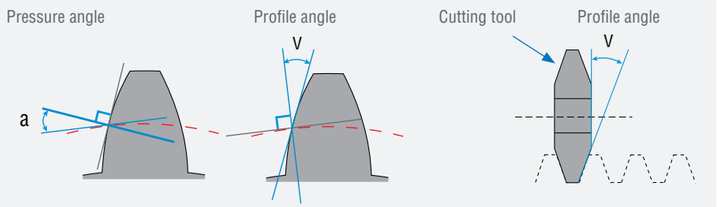
Pi.D = Gear perimeter = P.Z

Module "M" is defined as

$$M = \frac{P}{Pi} \Rightarrow M = \frac{D}{Z}$$

Key:

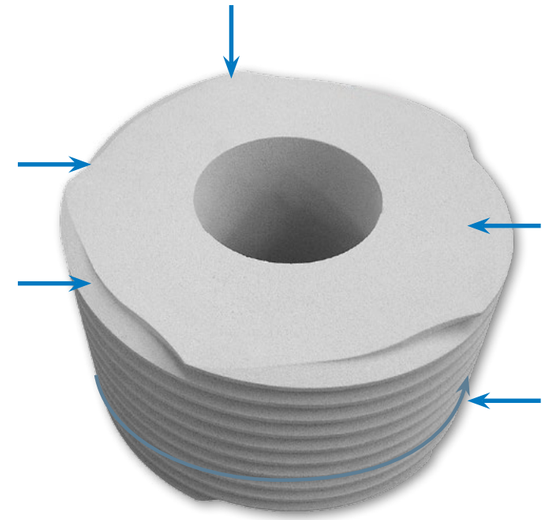
D = Pitch diameter
P = Circular pitch
M = Module
Z = Number of teeth



Number of entries (E): the number of threads of a worm wheel. As a general rule, E should:

- not be a multiple of the number of teeth (Z)
- be as high as possible (maximum 7)

Direction: rotational orientation (left or right) of the threads



Worm wheel with E=5 →
Direction: left (seen from top) →

UNDERSTANDING THE PARAMETERS

Use the information below as a guide to calculating the wheel parameters.

Part speed: PS (RPM) or (m/s)

Wheel speed: WS (RPM) or (m/s)

Number of entries: E

Number of teeth: Z

1. $$P_S = \frac{W_S \times E}{Z}$$

Choice of E (depends on Z, see example below)

Example calculation:

- gear with Z = 30
- max PS = 600 RPM
- max WS = 4000 RPM

Based on (1) $E = \frac{Ps \times Z}{Ws} \Leftrightarrow E = \frac{600 \times 30}{4000} = 4.5$

In this example, the general rule suggests 5 should be selected as the number of entries. However, 5 is a multiple of 30 so 4 should be chosen to optimize wheel speed.

The part speed is calculated by:

$$P_S = \frac{W_S \times E}{Z} \Leftrightarrow P_S = \frac{4000 \times 4}{30} = 533 \text{ RPM}$$

GEAR MANUFACTURING

Prior to grinding, a number of stages are involved in gear manufacturing:

Hobbing is a roughing operation which produces a gear profile with stock remaining for a final grinding process (see figure 1).

Hardening/Heat-Treating is a group of processes used to alter the physical, and sometimes chemical, properties of a material. Treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve to desired result such as hardening or softening of a material. Heat-treatment techniques include annealing, case hardening, precipitation strengthening (age hardening), tempering and quenching.

Grinding produces a high quality surface finish, correcting any distortion following heat treating, establishes profile dimensional accuracy. In some cases, grinding can be utilized to grind gears from solid eliminating the hobbing process.

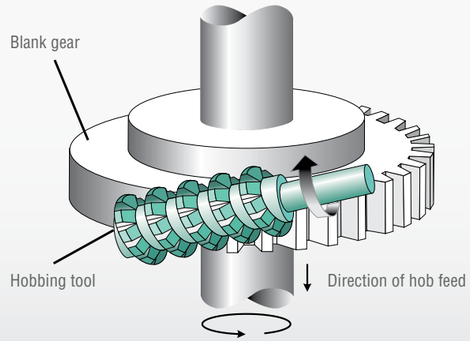


Figure 1: Gear hobbing

The process is determined by the production lot size. High production gears follow:

HOBBING → HARDENING → GRINDING

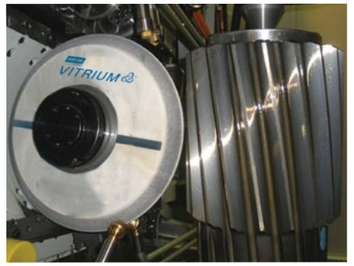
Utilizing grinding over hobbing for small lot quantities is common with the advanced grinding wheel technology of today.

GRINDING → HARDENING → GRINDING

MAIN GEAR GRINDING METHODS

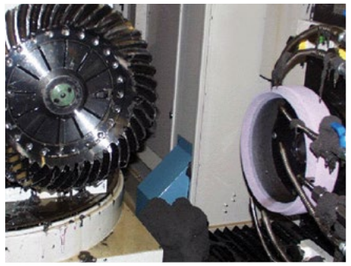
Continuous gear generation

Profiles an exact gear form into the workpiece. With multiple passes, the wheel grinds the gear teeth to produce the desired gear geometry.



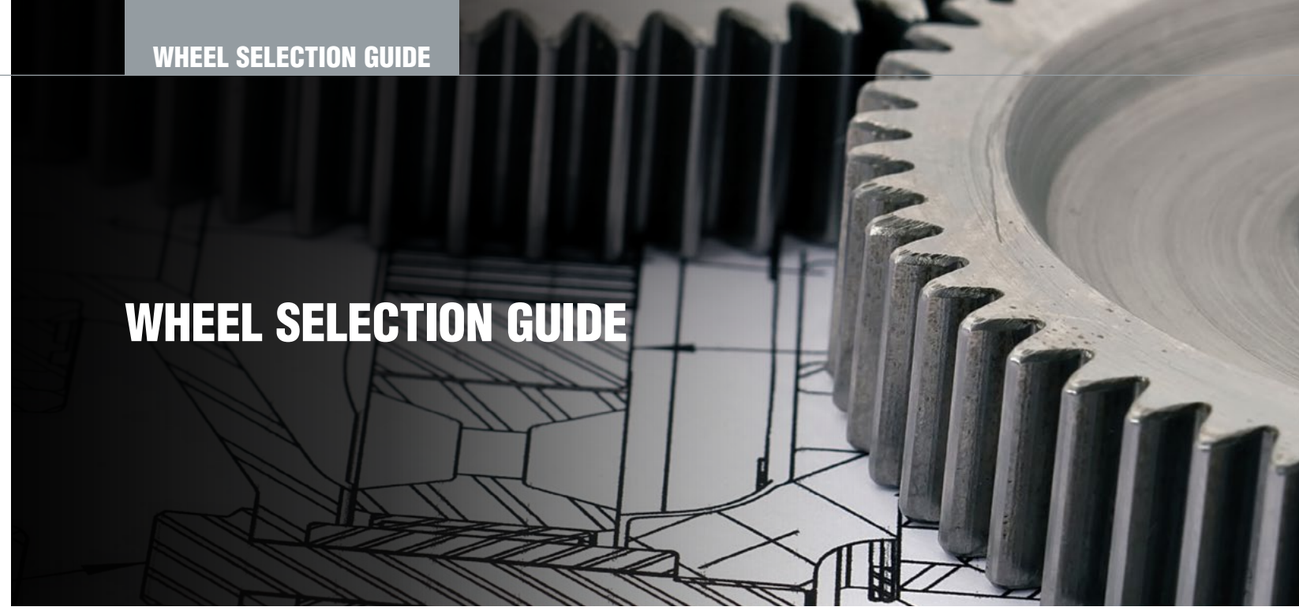
Profile grinding

Profiles the exact shape of the gear tooth. The wheel runs between two opposing teeth to grind both surfaces at the same time.



Bevel grinding

Bevel gears are conically shaped gears often used in differentials. Grinding of spiral bevel gears is performed with cup wheels following a profile grinding process.



WHEEL SELECTION GUIDE

PRODUCT DESCRIPTION

Use the following example as a guide when selecting wheel shape, profile and grit quality.

Dimensions (mm): 01 _ 300 x 125 x 160
(01 = Type; 300 = Diameter; 125 = Thickness; 160 = Bore)

Specification: 5NQM 90 H8 VS3G
(5NQM = Grain Type; 90 = Grain Size (mesh); H8 = Grade (hardness); VS3G = Bond; Structure)

GRIT SIZE SELECTION

The larger the gear module, the coarser the grit.

MODULE	GRIT SIZE			
	80	90	100	120
> 3.5	■			
1.5 - 3.5		■	■	
< 1.5				■

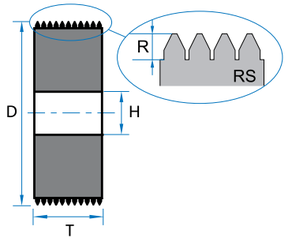
The grit sizes highlighted ■ with are recommended

Gear example:
120mm diameter, 36 teeth, pressure angle 20°,module “M” = 3mm

tip When designing a worm wheel, be sure to check the wheel construction parameters: module, pitch, number of starts, pressure angle, and thread direction.

WORM WHEEL FOR CONTINUOUS GEAR GENERATION

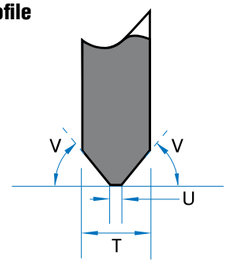
RS Profile



Key:
01 = Type
D = Diameter
T = Thickness
H = Hole
R = Thread depth, optional field

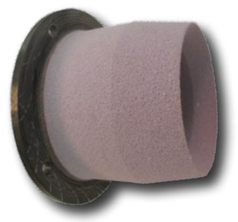
STRAIGHT WHEEL FOR PROFILE GRINDING

S Profile

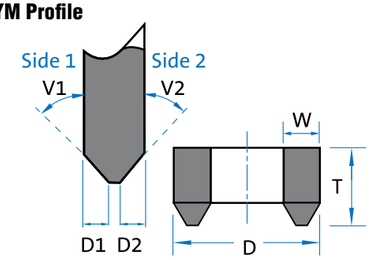


Key:
01 = Type
D = Diameter
T = Thickness
H = Hole
V = Angle, face point to side
U = Flat face width

CUP WHEEL FOR BEVEL GRINDING



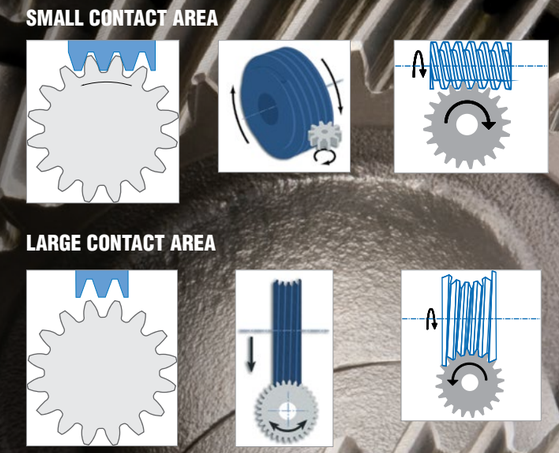
YM Profile



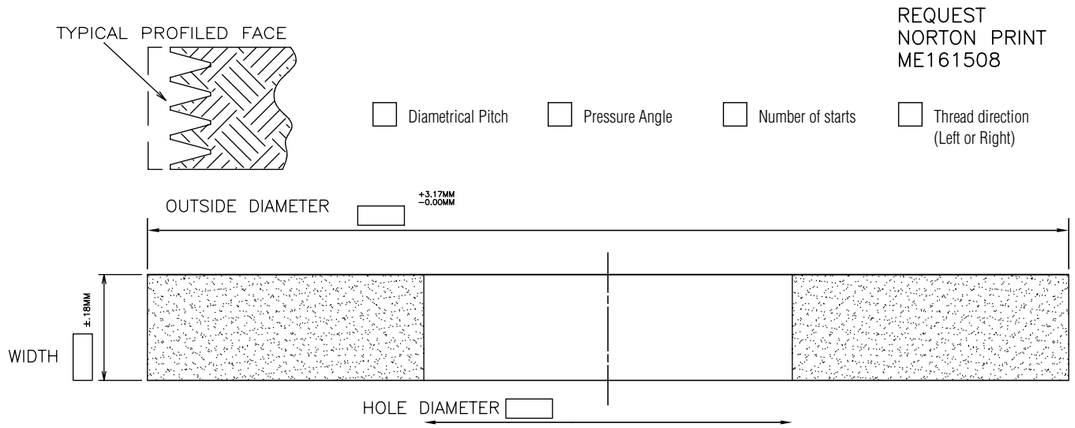
Key:
02 = Type
D = Diameter
T = Thickness
W = Rim thickness
V1 = Face angle side 1
V2 = Face angle side 2
D1 = Distance to point from side 1
D2 = Distance to point from side 2

CONTINUOUS GEAR GENERATION

Continuous gear generation profiles an exact gear form into the workpiece. With multiple passes, the wheel then works on the gear teeth to produce the desired gear geometry. This is known as continuous grinding and is mainly used on small contact areas, but can also be used on large contact areas.



WORM GRINDING WHEEL DESIGN WORK SHEET



GRIT DESCRIPTION

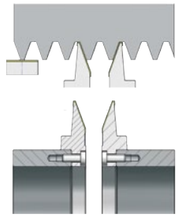
TIER	GRIT TYPE	FEATURES	BENEFITS
BEST	3NQM	▮ Engineered microstructure ceramic grain ▮ Sharp, friable ceramic technology	▮ Free cutting action ▮ Long life ▮ For low, medium and high force
BETTER	25A	▮ High purity friable abrasive	▮ Cool cutting ▮ Suitable for light to moderate feed rates

BOND DESCRIPTION

TIER	BOND TYPE	FEATURES	BENEFITS
BEST	VS3G	▮ Vitrified durable bond ▮ Latest generation bond	▮ Form holding ▮ Well suited for high-speed operations (80m/s) ▮ Long life

DRESSING TOOLS FOR CONTINUOUS GEAR GENERATION GRINDING WHEELS

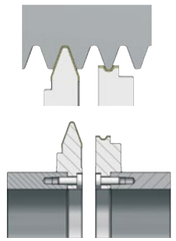
SINGLE-TAPER DRESSING DISCS



- Highly flexible tool concept for different module ranges
- Discs are mounted on separate spindles

Highly flexible solution

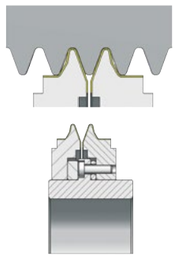
DOUBLE-TAPER DRESSING DISCS



- Very good when tooth root machining is required
- Tool design is dependent on the work piece

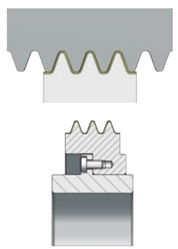
Module	Tool design
Small ≤1.5	Reverse electroplated
Large >1.5	Positive electroplated

ROLLER DRESSER SETS FOR SINGLE-PASS DRESSING



- High pitch adjustment
- Very good when tooth root grinding is required
- Tool design is dependent on the workpiece

FULL PROFILE ROLLER DRESSERS

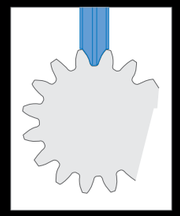


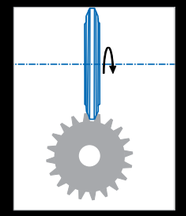
- Particularly suitable for modules ranges < 1.5
- Excellent tool design with low setup requirements
- Specific design to each workpiece

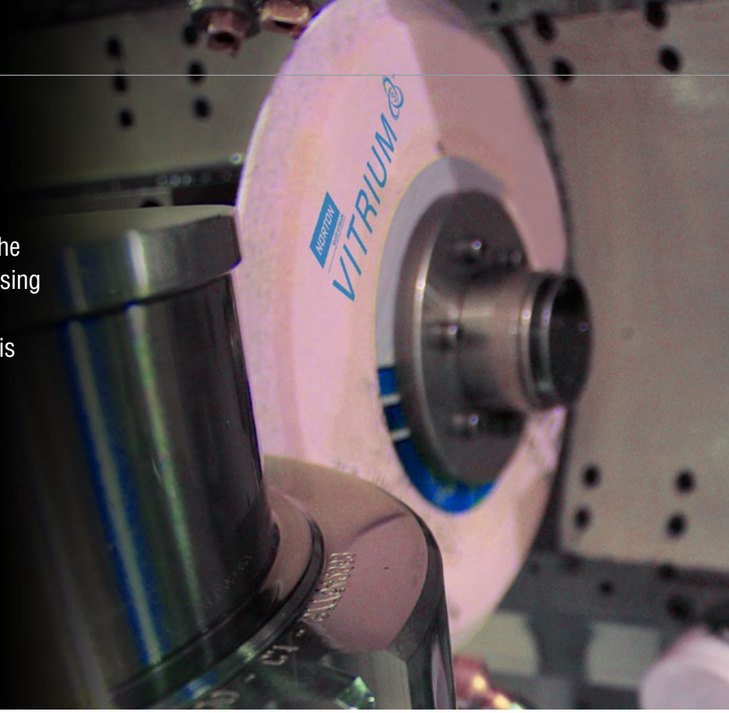
Highly productive solution

SINGLE RIB GRINDING

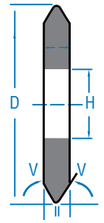
Single rib grinding forms the exact shape of the gear teeth. The wheel runs between two opposing teeth to grind both surfaces at the same time. This is known as discontinuous grinding and is used on large contact areas.

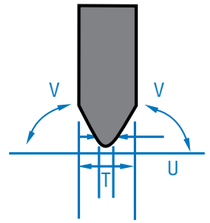






WHEEL SELECTION GUIDE





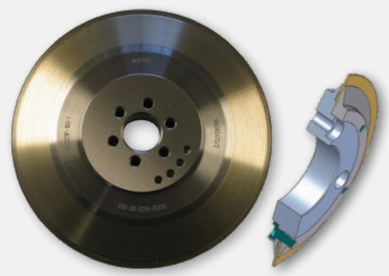
Key:
01 = Type
D = Diameter
T = Thickness
H = Hole
V = Angle, face point to side
U = Flat face width

NORTON SAINT-GOBAIN

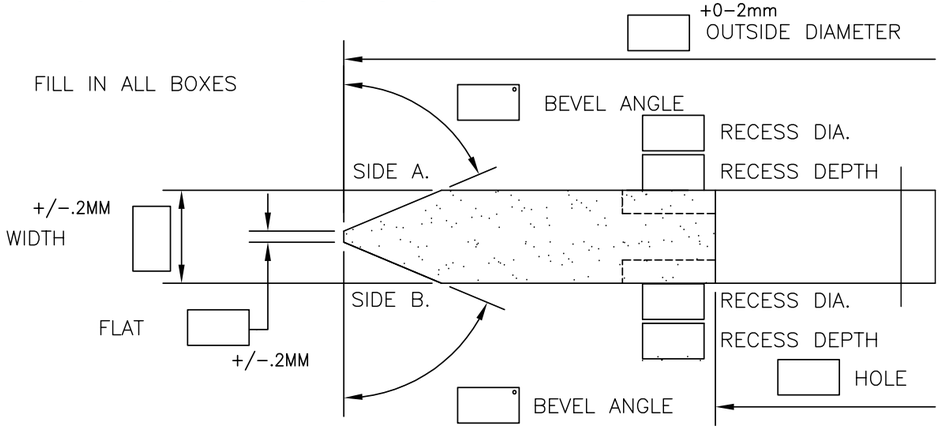
DRESSING TOOLS

Norton rotary dressing discs provide excellent results on single profile wheels:

- Contour controlled CNC dressing
- Very flexible
- One tool for several profiles



SINGLE RIB GRINDING WHEEL DESIGN WORK SHEET



REQUEST
NORTON PRINT
ME161178

WHEEL MAY OR MAY NOT BE RECESSED

GRIT DESCRIPTION

TIER	GRIT TYPE	FEATURES	BENEFITS
BEST	3TGP	▮ Blend of ceramic with pink aluminum oxide ▮ Long, sharp ceramic grain	▮ Free cutting ▮ Self sharpening
BETTER	25A	▮ High purity friable abrasive	▮ Cool cutting ▮ Suitable for light to moderate feed rates

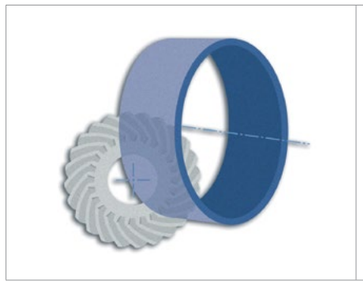
BOND DESCRIPTION

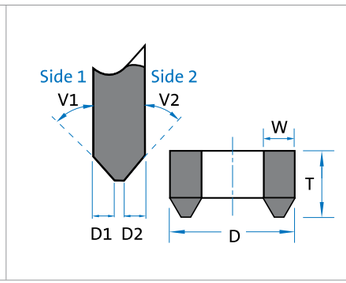
TIER	BOND TYPE	FEATURES	BENEFITS
BEST	VS3G	▮ Vitrified durable bond ▮ Latest generation bond	▮ Form holding ▮ Well suited for high-speed operations (80m/s) ▮ Long life

SPIRAL BEVEL GEAR GRINDING WHEELS

Bevel gears are conically shaped and used for differentials. Grinding of spiral bevel gears is performed with cup wheels in a specific profile grinding process.

WHEEL SELECTION GUIDE





CUP GRINDING WHEEL DESIGN WORK SHEET

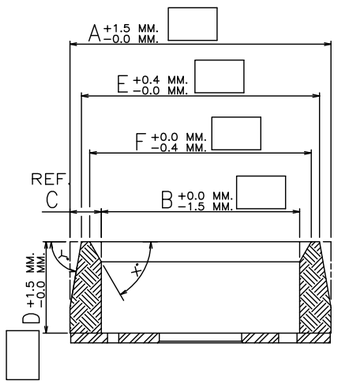


PLATE DATA DESIGN INFO

FILL IN ALL BOXES

- PLATE NUMBER IF KNOWN
- PLATE DIAMETER
- PLATE HOLE DIAMETER
- PLATE THICKNESS (.250"/.375")
- PLATE BOLT CIRCLE # 1
  - NUMBER OF HOLES
  - HOLE SIZE
  - TYPE
  - SPACING
  - CORD
- PLATE BOLT CIRCLE # 2
  - NUMBER OF HOLES
  - HOLE SIZE
  - TYPE
  - SPACING
  - CORD
- PLATE BOLT CIRCLE # 3
  - NUMBER OF HOLES
  - HOLE SIZE
  - TYPE
  - SPACING
  - CORD

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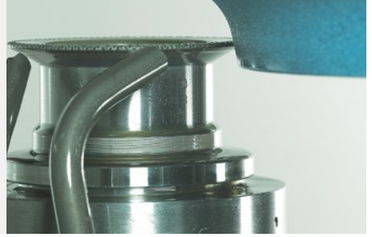
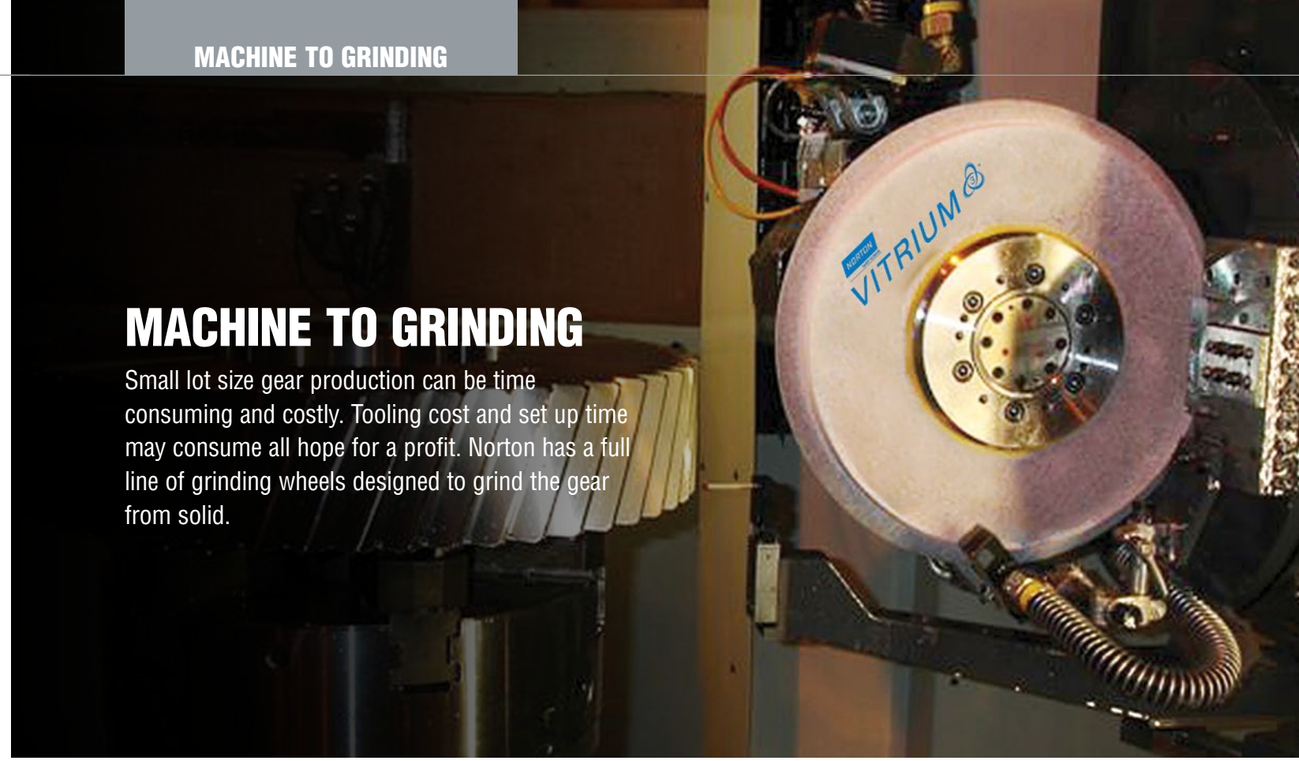
NORTON SAINT-GOBAIN

DRESSING TOOLS

Norton offers a dressing solution for all spiral bevel gear grinding wheels:

- Contour controlled CNC dressing
- Very flexible
- One tool for several profiles





MACHINE TO GRINDING

Small lot size gear production can be time consuming and costly. Tooling cost and set up time may consume all hope for a profit. Norton has a full line of grinding wheels designed to grind the gear from solid.

MACHINING TO GRINDING FOR SMALL LOT SIZE GEAR PRODUCTION

- Machining to grinding eliminates rough cutting the gears (through the use of formed cutters, broaching or hobbing)
- Grinding from solid eliminates the need for a cutting machine and all the complementary tooling and equipment required to start and maintain the rough cutting operation
- Typically a rough-ground gear will be of higher quality than a hobbed, near-net, or cut hear – particularly larger spur gears and gear sets
- Norton machining to grinding (MTG) wheel specifications create the flexibility to combine grinding in the soft state from solid, to hard finishing – with only 1 grinder

MTG CASE HISTORY

Spur and Helix Gear Sets

Grinding spur and helix gear sets from solid at a large gear manufacturer.

Customer Assessment

- Norton engineers were approached by a customer interested in improving grind cycle times on large gears
- This customer typically manufactures and repairs 2,500+ large gears and gear boxes per year
- A large backlog at the customer's cutting machine was creating late ship dates and preventing the customer from accepting new orders
- Customer contacted OEM and Norton for assistance in speeding up grind cycle and to explore the possibility of grinding gears from a solid
- Development work by OEM and Norton application engineer proved that gears could be efficiently ground from solid, and then finish-ground on the same machine after heat treat as required

Test Data

Wheel Size:	457mm X 127mm
Wheel Type:	01, face bevel 2 sides 30 degrees
Wheel Specification:	TGX-VTX2
Workpiece Material:	4340, Hardness: 38-42 Rc
Spur/Helix Gear:	115 teeth
	58.370" OD, 8" face width
	30º helix angle, whole depth .990"
	D.P. 2.3, 25 degree P.A., AGMA 12
Machine Model:	Hofler Grinder, 32 hp

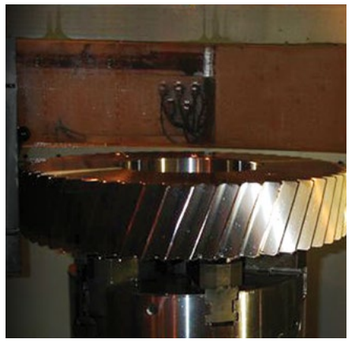
Wheel Speed:	5,500 SFPM
Coolant:	Straight oil, high pressure system - chilled and filtered 70 GPM @ 75-80 PSI
MTG Rate of Cut:	3.0 cubic inches per minute
Dresser Type:	Rotary
Truing/Dressing:	Dress every 5 teeth; dress .0009" x 4 passes
Peak Power Steady State:	11hp

TEST RESULTS

	HOBBING AND GRINDING	MACHINE TO GRINDING	SAVINGS
Process Time	1,200 minutes	949 minutes	21%
Tooling Cost	$568.25	$244.76	57%
Total Cost	$2,968.25	$2,618.79	12%

HOBBING PROCESS

GRINDING FROM SOLID



TGX-VTX2 ENGINEERED FOR MACHINING TO GRINDING

SEMI-FINISHED STOCK AVAILABILITY

Saint-Gobain Abrasives now offers a stock of semi-finished straight wheels, ready to be profiled on demand. This stock is designed to provide a fast track service and to increase flexibility.

The table below is a guide to selecting the best product solution for the machine brand and type. Contact your local sales representative for more information.

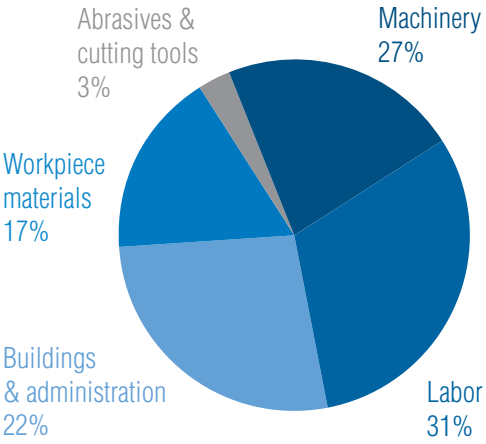
WHEEL DESIGN	WHEEL DIMENSION	SPECIFICATION	PART #
Worm Wheel	280 x 160 x 115	NQ80-H8VS3G	00310448492
	280 x 160 x 115	25A80-H8VS3G	00310448494
	350 x 125 x 160	3NQ90-H10VS3G	310448495
	350 x 125 x 160	25A90-H10VS3G	310448496
Single Rib Wheels	450 x 150 x 127	3TGP80/3-G12VS3G	00310448497
	450 x 100 x 127	3TGP80/3-G12VS3G	00310448498
	450 x 50 x 127	3TGP80/3-G12VS3G	00310448499
	300 x 60 x 50.8	3TGP80/3-G12VS3G	00310448500
	300 x 30 x 50.8	3TGP80/3-G12VS3G	00310448501
	120 x 30 x 20	3TGP80/3-G12VS3G	00310448502

NORTON SAINT-GOBAIN PSP process solutions program

TYPICAL COST REDUCTIONS

On average, abrasives and cutting tools only account for about 3% of total manufacturing budgets. Norton Vitrium^3 products optimized with Norton's proprietary PSP (process solutions program) helps to optimize your total cost and improve your productivity.

For information on how to achieve the greatest overall cost savings, see the example below or go to www.nortonindustrial.com/psp.aspx.



Decreasing the price of abrasives
A 30% price reduction will **only** reduce costs per part by **1%.**

1%

Increasing the life of abrasives
Even a 50% increase in product life will **only** reduce costs per part by **1%.**

1%

Increase overall productivity through PSP
With a 20% decrease in cycle time per part, there will be a **reduced total cost** per part of **more than 15%.**

PSP 15%

ENVIRONMENTAL BENEFITS

GREEN TAG™

IMPROVING OUR CARBON FOOTPRINT

Increased productivity with existing customer machine capacity. Able to work with higher feed rates, speed and pressure, to significantly increase production while using fewer wheels.

Reduced energy consumption with optimal firing temperatures during manufacturing of Norton Vitrium3 wheels.

By choosing Norton Vitrium3 technology for your grinding operation, you help to preserve the environment. In addition, Norton Vitrium3 eliminates costly re-validation of processes associated with using certain chemicals.

www.facebook.com/**nortonindustrial** | www.youtube.com/**nortonindustrial** | www.**nortonabrasives.com**

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