Problem Solving Tips

02

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KEY WORD

Extended Dressing Interval

Reduced Grinding Burn

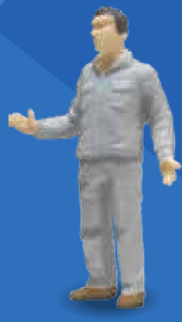
Reduced Tool Cost

Improved Productivity

High Precision

Q

I want a grinding wheel that meets all of the following requirements: reduced tool costs, extended wheel life, and eliminate grinding burn.



A

For these concerns, try:

A Wheel that Achieves Both High Precision and Low Costs in Gear Grinding

Gear Grinding Wheel
Gear Ace

We have developed a new gear grinding wheel that maintains high cutting ability and extends dress intervals even under specific gear grinding dressing conditions where grinding burn can easily occur. The A-type grain* used with this wheel has high dressability and a dress interval similar to that of a ceramic wheel, reducing the costs of both wheel and dresser.

Problems with the Continuous Generating Gear Grinding Process

* Gear grinding in this report shows continuous generating gear grinding.

Gear grinding is one of the machining methods used in the final finishing process of gear tooth surfaces. Before 1990, gears requiring a grinding process were limited, and the process required from 5 passes to as many as 9 or 10 passes in some cases and the wheel speed was as slow as 30 to 45 m/s, resulting in long cycle times. The grinding wheels used for this were made with A-type conventional grains such as WA, PA, SN or some combination of these. There was no significant difference from general purpose cylindrical grinding wheels. However, in recent years, the demand for fuel efficiency and quietness in the automotive industry drove the need for higher quality gears which require a grinding process. As a result, the demand to improve the productivity of the gear grinding process has increased. To meet the demand, the control systems for gear grinding machines have advanced remarkably, the gear grinding process can be drastically shortened to 2 or 3 passes, and the grinding wheel speed has been increased to as much as 75 m/s. To achieve such high efficiency grinding, ceramic grains have come to be used for gear grinding. Noritake recommends the conventional A-type grain, MA/SN*, for dressability, and the ceramic grain, CXY, for grinding efficiency (Fig. 1).

Fig. 1 Gear Ace (Left: CXY Wheel, Center: TA Wheel, Right: MA/SN Wheel)

However, from the knowledge we've accumulated in our experience with gear grinding, Noritake thinks it is difficult for ceramic grains to achieve their full potential with gear grinding. Ceramic is a high-performance grain, but the mechanism that causes it to perform well differs greatly from the mechanism that causes A-type conventional grains to work well. When grinding, and especially in high-efficiency grinding, A-type conventional grains can undergo loading. As loading increases, so does grinding force, which then causes grinding burn and causes the grains to break down, leading to shape inaccuracies in the workpiece. On the other hand, ceramic grain, characterized by micro fracturing, and self-sharpening* suppresses loading and is effective for maintaining shape while reducing grinding burn (Fig. 2).

The mechanism of gear grinding is similar to worm drive where a worm meshes with a worm wheel. In gear grinding, the grinding wheel is the worm and the workpiece is the worm wheel. The teeth are ground while the grinding wheel and the workpiece are meshed with each other. Theoretically, the trajectory of contact between the grinding wheel and the workpiece is linear. Additionally, since the work piece continuously travels across the width of the wheel, compared to cylindrical grinding and surface grinding where each grain is used in every rotation, the grain use is incredibly low (Fig. 3, 4). Therefore, since the mechanism which allows ceramic grains to exhibit high performance, (i.e., a cycle of loading → microfracture → loading → microfracture) is less frequent, it's harder to take advantage of the ceramic grain's strengths compared to cylindrical or surface grinding.

Plus, since the gear grinding process has a higher tool cost than other machining and grinding processes, it is important to offer grinding wheels capable of reducing tool cost and eliminating grinding burn.

Fig. 2 Differences between Ceramic Grain and A-type Conventional Abrasive Grains

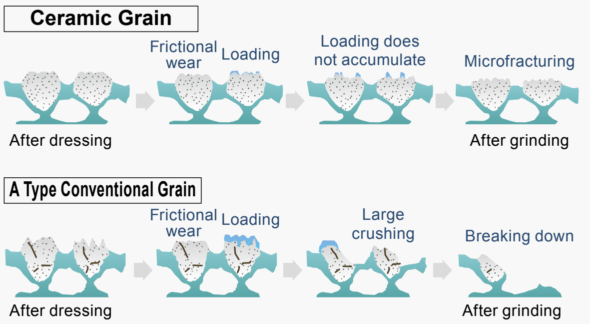


Fig. 3 Schematic Diagram of Gear Grinding

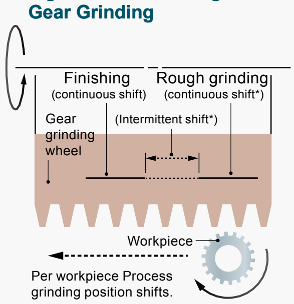
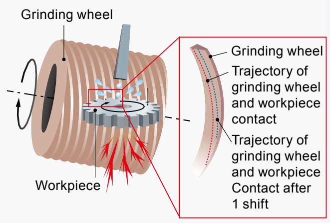


Fig. 4 Trajectories of Contact between Grinding Wheel and Workpiece



Using the A-Type Conventional Grain with the Most Toughness* - The TA Grain

The grinding condition of recent gear grinding is classified as high-efficiency grinding. Therefore, even though it's hard to take advantage of the mechanism by which ceramic grains work as stated above, since conventional grains such as WA, PA, and SN have problems such as large grain fracturing, ceramic grains still allow for better productivity. However, because of the unique grinding process shown in Fig. 3 and Fig. 4, we believe that a grain that's tough while still dressable would be the best grain within the current range of gear grinding efficiency.

Noritake's proprietary grain, TA, is the toughest conventional A-type grain, and is well-suited for gear grinding. Using the TA grain, we have developed a new gear grinding wheel called the TA grinding wheel [1], which focuses on wheel life, and TA2 grinding wheel, which achieves both wheel life and cutting ability.

Improving Productivity - The TA Grinding Wheel

In testing how much the TA wheel extends the dress interval*, we were able to confirm a 250% longer interval than that of an MA/SN wheel (Table 1, Fig. 5).

Table 1 Test Conditions

[Grinding Wheel]

Dimension	φ300 × T125 × φ160 mm
Specification	TA-VLK1P(TA grinding wheel)
	MA/SN-V36P

[Dressing Conditions]

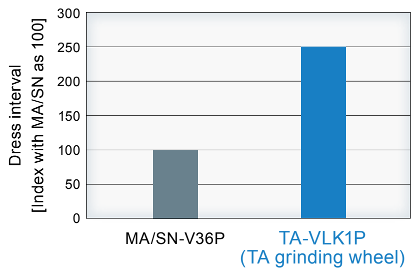
Dresser type	-	Composite roll type*	
Dressing process	-	Rough grinding	Finishing
Grinding wheel speed	min^{-1}	100	50
Dresser speed	min^{-1}	4000	4000
Cutting depth	mm	0.025	0.02

[Grinding Condition]

Grinding machine	-	Gear grinding machine		
Grinding method	-	Continuously generating gear grinding		
Workpiece materials and dimensions	-	SCM420 φ200 × T40 mm		
Module*	-	2.0		
Pressure angle*	°	15		
Number of the teeth	Sheet	50		
Grinding process	-	Rough grinding	Semi-finishing	Finishing
Grinding method	-	Conventional*	Climb*	Conventional
Grinding wheel RPM	min^{-1}	4500	4500	4500
Cutting depth	mm	0.20	0.15	0.05
Axial feed*	mm / rev	1.2	1.0	0.5
Grinding efficiency*	mm^3 / s	250	150	20
Coolant	-	Straight oil		

Extending the dress interval also leads to reduced cost-per-piece, which translates to lower tooling cost, and can also contribute to improved productivity by shortening overall dress time (dress time/dress interval) and reducing the downtime caused by wheel change. The TA wheel shows the same grinding performance as a ceramic wheel within a certain efficiency range.

Fig. 5 Extension of Dressing Interval in TA-VLK1

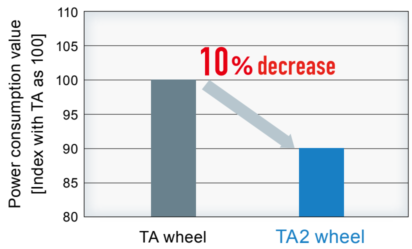


Contributing to Tool Cost Reduction and Grinding Burn Elimination - The TA2 Wheel

As mentioned above, using the TA grain has significantly extended the dressing interval, but Noritake has also developed the new TA2 grinding wheel that improves on the TA wheel, giving it a better cutting ability capable of avoiding grinding burn. TA2's power consumption during gear grinding is 10% less than that of TA, and since the cutting ability is improved, it effectively prevents burning (Fig. 6).

Although TA grain is a tough grain, the dresser wear is equivalent to that of conventional A -type grains, but the TA2 wheel improves the cutting ability of the TA wheel, dresser wear is even lower, resulting in a longer dresser life. Since cost for dressers is higher than it is for grinding wheels in gear grinding, this adds even more to tool cost savings.

Fig. 6 Gear Grinding Power Consumption Value: TA Grinding Wheel vs. TA2 Grinding Wheel



Case studies of TA and TA2 Wheel in Gear Grinding

As described above, the TA wheel and TA2 wheel are superior to conventional A-type wheels in terms of dressing interval extension and preventing grinding burn. In addition, since they can help lower tooling costs, many customers are using them and getting good results for gears of all shapes and sizes. We hope that the information provided in this article will be useful for those looking into Noritake's gear grinding wheels.

[Notes]

* A-type conventional abrasive grains: Aluminum oxide grain.
* MA/SN grinding wheel: A grinding wheel made of a combination of the A-type conventional grains MA and SN.
* Self-sharpening: When the grain tips wear and dull, the grain fractures locally generating a new cutting edge. When the holding force of the grain falls below a certain level through repeated fracturing, the grain eventually falls out, and new grains from inner layer are exposed, maintaining the cutting ability.
* Toughness: Refers to a grain's resistance to fracture.
* Dress interval: Number of workpieces between dresses.
* Composite roll type: One type of dresser used in gear grinding. A rotary dresser that shapes the grinding wheel one tooth at a time and the tooth tip, tooth flank, and tooth root are molded simultaneously.
* Module: A measure of gear tooth size.
* Pressure angle: The angle between the normal vector of the tooth face and the radial direction (in the case of an involute gear).
* Conventional cut: Grinding process in which the feed of the grinding wheel proceeds from top to bottom with respect to the workpiece (up-cut).
* Climb cut: Grinding process in which the feed of the grinding wheel proceeds from bottom to top with respect to the workpiece (down-cut).
* Axial feed: The vertical displacement (Z-axis direction) of the grinding wheel per revolution of the workpiece during one machining pass.
* Grinding efficiency: Volume of workpiece removed per hour.

[Reference]
[1] Hiroshi Oyama: Life King, NORITAKE TECHNICAL JOURNAL 2018 (2017), 28

Q **How do I choose between using TA wheel and TA2 wheels?**

A It depends on the type of grinder, processing conditions, dressing conditions, and coolant type. TA is recommended if shape retention is required, and TA2 is recommended if grinding burn is likely to occur.

Q **Can TA and TA2 wheels be used in the same grinding condition as ceramic wheels?**

A Depending on the grinding efficiency, yes.

Q&A

[Scope of Application and Expected Benefits]

Metallic material		Non-metallic material		Other
Ferrous material	Non-ferrous material (Al, etc.)	Inorganic material (glass, ceramics)	Organic material (rubber, plastic)	Advanced material
●				

Shorter cycle time	Improved tool life	Improved machining quality	Improved workability	Environmental consideration
●	●	●	●	