



## **AGMA Technical Paper**

# **Performance and Technological Potential of Gears Ground by Dressable cBN Tools**

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

## Abstract

Dressable vitrified bond cBN grinding tools combine the advantages of other common tool systems in generating gear grinding. The cBN grains are a highly productive cutting material due to their high specific stock removal rate. Vitrified bonds are dressable and thereby very flexible: By dressing different profile modifications can be set up and constant gear quality can be guaranteed during the tool life time. Despite those technological advantages there is only a small market distribution of these grinding tools due to high tool costs. Furthermore, only a few published scientific analysis of generating gear grinding with dressable cBN exist. Especially, the influence of the grinding tool system on manufacturing related component properties has not been analyzed yet. The research objective of this report is to determine the advantages of dressable cBN tools in generating gear grinding.

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## Introduction

In order to improve load carrying capacity and noise behavior case hardened gears usually are hard finished. One possible process for hard finishing of gears is generating gear grinding which has replaced other grinding processes in batch production of small and middle gears due to high process efficiency. Depending on grinding task and batch size different tool concepts can be used in generating gear grinding. The latest concept is dressable vitrified bond cBN grinding tools.

Dressable vitrified bond cBN grinding tools combine the advantages of other common tool systems in generating gear grinding. The cBN grains are a highly productive cutting material due to their high specific stock removal rate. Vitrified bonds are dressable and thereby very flexible. By dressing different profile modifications can be set up and constant gear quality can be guaranteed during the tool life time. Despite those technological advantages there is only a small market distribution of these grinding tools due to high tool costs. Furthermore, only a few published scientific analyses of generating gear grinding with dressable cBN exist. Especially, the influence of the grinding tool system on manufacturing related component properties has not been analyzed yet.

## State of the art

### Generating gear grinding

One of the most efficient processes for the hard finishing of gears in batch production of external gears and gear shafts is the continuous generating gear grinding. Generating gear grinding is used for the hard finishing of gears with a module of  $m_n = 0.5 \text{ mm}$  to  $m_n = 10 \text{ mm}$  [1], [2], [4]. By the application of new machine tools, the process can be used for grinding large module gears (up to  $d_a = 1,000 \text{ mm}$ ) [4].

The cylindrical grinding worm, whose profile equates a rack profile in a transverse section, hobs with an external gear, Figure 1 (left). The involute is generated by continuous rolling motion of the grinding worm and workpiece by the profile cuts method [5], [2]. Profile cuts method in the generating processes means the profile form is generated by a finite number of profiling cuts. Due to the closed grinding worm no generating cut deviations, known from gear hobbing, occur in generating gear grinding.

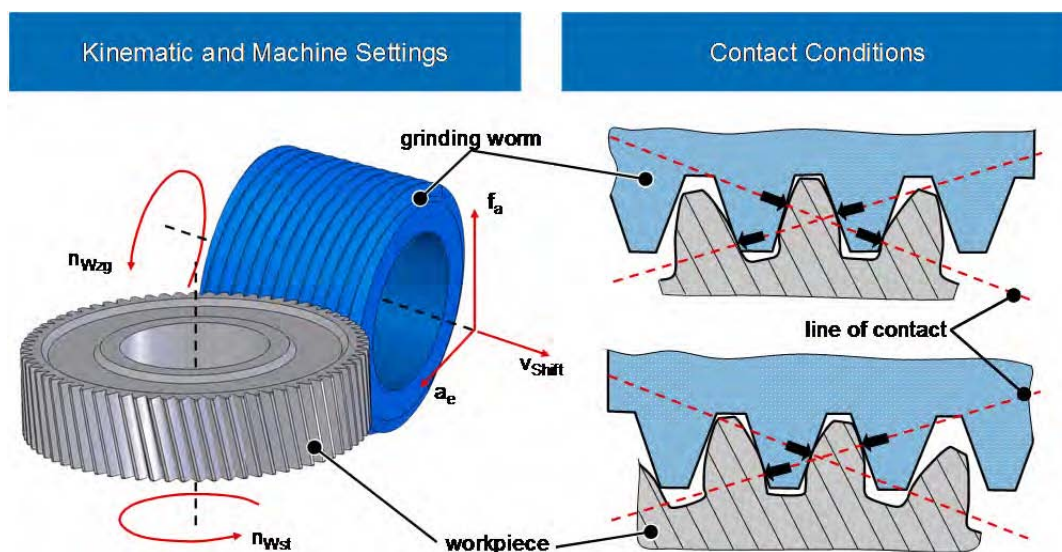


Figure 1. Generating gear grinding – principle, machine settings and contact conditions (© WZL)

In comparison with other gear grinding processes, the stock removal rate in generating gear grinding is very high. In most cases, it is only limited by the reachable gear quality [2]. In generating gear grinding, always multiple points of the grinding worm are in contact. The number of contact points change continuously during the tool rotation, **Error! Reference source not found.** (right).

The contacts on the right and on the left tool flank are equal by an even number of contact points. This leads to an consistent distribution of forces. By an uneven number of contact points also the distribution of forces will be uneven. This leads to an inconsistent distribution of the cutting forces. In the example in Figure 1, lower on the line of contact of the left tool flanks the forces are split in two contact points. On the right tool flank the cutting force is increased, because only one point has contact. This fact can lead to a higher stock removal at this contact point and to a higher excitation. The consequence can be the appearance of profile form deviations which reduce the reachable gear quality. Scientific publications of Meijboom [6] and Türich [7] describe this relation theoretical.

Publications, e.g. in [8], [9], [10], and existing doctoral thesis of Meijboom [6], Türich [7] and Stimpel [11] show the influence of several parameter (e.g. axial feed, number of starts) on the process results. But several technological correlations have not been analyzed or verified in trials yet. Especially, investigations on different tool systems cannot be found in literature so far.

### **Tool systems in generating gear grinding**

In gear grinding usually two types of tool system are used. On one hand for small batch production with changing gear geometries and modifications flexible solutions are needed. Therefore, dressable vitrified bond grinding wheels made of corundum are used. A huge advantage is constant gear quality and surface roughness due to the possibility of dressing. A disadvantage can be found in short tool life times and additional dressing time.

On the other hand, for mass production with only a few variants concerning profile modifications a productive grain material is needed. Therefore, electroplated cBN tools are used. In contrast to dressable vitrified bond corundum tools electroplated cBN has a higher productivity due to wear-resistant grain material. A huge advantage is time saving due to reduction of dressing processes. But disadvantages can be found in changing gear quality during tool life time and the significant higher tool costs.

To combine the advantages of both tool systems vitrified bond dressable cBN tools have been developed. Due to high tool costs and existing risk in tool handling this tool system has not been used in many industrial applications so far. Furthermore, only a few published scientific analysis of generating gear grinding with dressable cBN exist [13], [14], [15]. Especially, the influence of the grinding tool system on manufacturing related component properties has not been analyzed yet. But due to new developments, since a few years the tool system gets more and more attractive for industrial applications [12].

### **Objective and approach**

The research objective of this report is to determine the advantages of dressable vitrified bond cBN tools in generating gear grinding. The manufacturing related properties of gears which are ground with dressable cBN will be analyzed and compared with conventional ground gears.

The tested gear sets are manufactured identically despite the gear hard finishing process. In generating gear grinding different tool systems are used for the hard finishing. The properties, e.g. surface structure, residual stresses and gear quality, are analyzed and compared.

After gear grinding pitting tests according to the DIN-ISO standard for low cycle fatigue area are carried out [16], [17]. In the end a relation between different tool systems, manufacturing related properties and fatigue strength will be deducted. Furthermore, first results showing the tool wear behavior will be shown.

### **Performance of CBN-ground gears in fatigue tests**

In the following section the performance, especially the flank fatigue strength, of gears ground by different grinding tools will be investigated in pitting tests. Therefore, gear geometry, initial situation of the ground gears, test rig, and test approach is described. Afterwards sample results will be shown.