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A Methodology for the Evaluation of CBN Abrasive Grits

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Keywords: Grinding; Super abrasive; Cubic boron nitride (CBN); Electroplated wheel; Vitrified bond wheel

Abstract

A better understanding of the grinding process is essential for newly developed grit types. Mapping the effect of grain properties to the application performance is the ultimate goal of every grit manufacturer. The challenge is, however, to provide crucial information about the grit and, at the same time, distinguishes it from other possible effects such as: porosity, adhesion and bond strength. A series of grinding tests have been conducted using different grit types and bond systems and a novel testing methodology implemented. The results have shown good sensitivity with respect to the grain properties and, consequently, the potential application of this method to grinding process optimization.

Introduction

Cubic boron nitride (CBN) is vital in grinding of automotive parts, the advantages over conventional abrasives make it an attractive choice due to improved production through longer dressing intervals, greater part consistency and ability to achieve high tolerances [1]. Although, the number of CBN abrasives has grown considerably over recent years, the challenge of understanding the performance benefits of various CBN abrasive grains still remains, whether used in vitrified bond or single layer tool. There is a general requirement from the grinding industry to produce tougher grits since it is perceived to provide an improved performance.

A considerable amount of work has been carried out in order to analyze abrasive grains in different grinding applications [2-5]. Breder et al. have found the friability of abrasive particles to be the key performance parameter, which relates to grain wear during grinding in electroplated tool application [2]. Later, Upadhyaya & Fiecoat showed that not only the toughness of material influence grinding behavior but also the shape and chemical composition of grits [4]. Vitrified bond wheels have also been extensively investigated – Hitchiner & McSpadden observed a trend of improved performance when vitrified bond strength is matching the toughness of the grit [5].

For a grit manufacturer it is essential to understand the abrasive grain differences; not only material characteristics but also the performance in grinding application. Standard techniques are available to determine the abrasive grain properties, however, only limited attempts have been made to establish correlation between grinding performance and grit properties [2].

In this context, this paper deals with a series of grinding tests with the objective to identify critical grit properties for particular grinding application.

Methodology

The maximum chip thickness is a fundamental parameter for the understanding of a grinding process [6]. As a simplified version of the maximum chip thickness, *Aggressiveness*, is used here [7], [8]. An optimal *Aggressiveness* will form large enough chip to avoid excessive rubbing and high specific grinding energies, but not large enough to cause excessive grinding wheel wear. *Aggressiveness* is calculated as:

$$Aggressiveness = 10^6 \cdot v_w/v_s \cdot (a_d/d_s)^{1/2} \quad (1)$$

Where $10^6 \cdot v_w/v_s$ is the ratio of wheel and workpiece speeds, a_d is the depth of cut [mm] and d_s is the wheel diameter [mm].

Specific grinding energy is an indicator of grinding efficiency. It shows required energy to remove a unit of material using particular grinding set up. The specific grinding energy u is calculated as [6]:

$$u = P/MRR \quad (2)$$

where P is the grinding power [W] and MRR is the material removal rate [mm^3/s].

Another important parameter for assessing the vitrified bond wheels is the G-Ratio (Eq. 3), which is a relative measure of wheel wear:

$$G\text{-}Ratio = V_m/V_w \quad (2)$$

where V_m is workpiece material ground [mm^3] and V_w is the volume of wheel worn [mm^3].

A testing methodology has been applied with the objective to evaluate and understand the performance differences of the existing and newly developed abrasive grit types.

Initially, each abrasive has been tested over a wide range of aggressiveness (i.e. window of operation test). This gave an understanding of grinding efficiency, and the identification of an area where mostly rubbing is present (low aggressiveness), as well as region of high aggressiveness where excessive wheel wear is expected. Fig. 1 shows the optimal aggressiveness in the grinding "sweet spot", which gives lower and balanced grinding conditions with respect to surface finish and wheel wear [9]. The determination of the grinding "sweet spot" was done subjectively via grinding experiments. Corresponding parameters are the base for extended wear testing of the wheel.

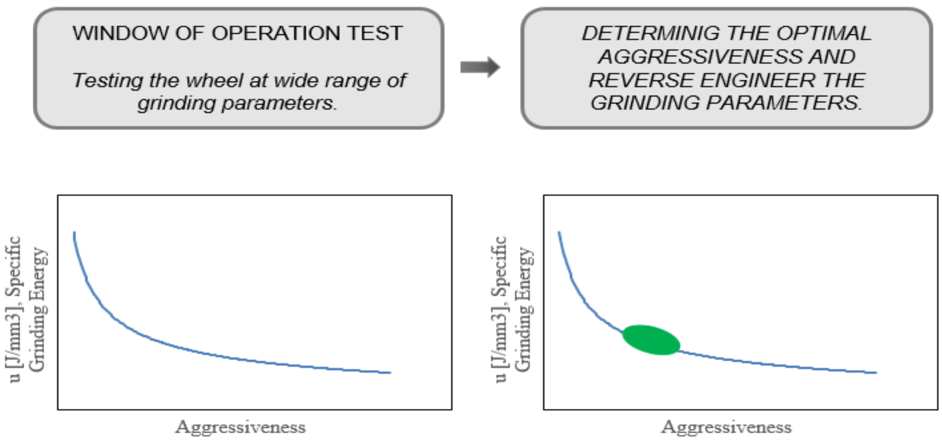


Figure 1: Methodology for internal testing of grinding wheels.

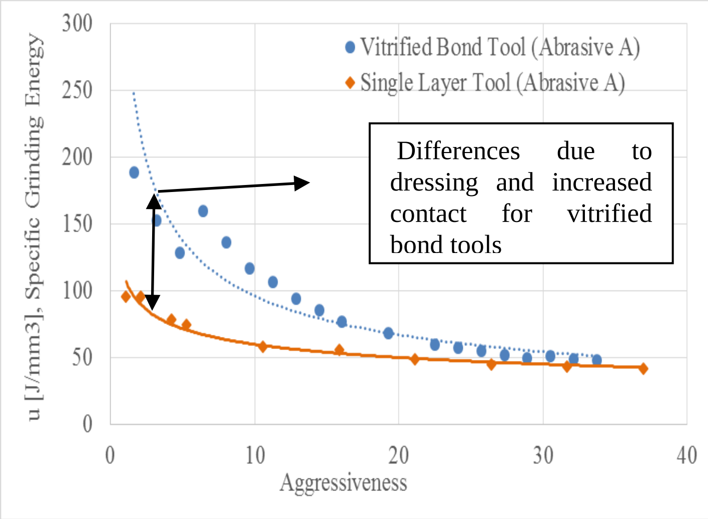
Grinding experiments were conducted on Blohm Profimat MT 408, surface grinder. Two types of grinding wheels were tested: electroplated and vitrified bond wheels (see Table 1). Several grinding trials were conducted with four abrasive grit types. The forces were measured with a 3-component Kistler dynamometer (Type 9257A).

Table 1: Grinding wheel specifications and dressing parameters.

	VITRIFIED BOND WHEEL	ELECTROPLATED WHEEL
wheel size	300mm	250mm
CBN abrasive size	#120/140 (B126)	#120/140 (B126)
Concentration	C125	Full
abrasive layer thickness	3mm	single layer
dressing process	YES	/
U_d- dressing overlap ratio	4	/
a_e- dressing depth	3µm	/
q_d- dressing speed ratio	+0.8	/

Results and Discussion

The grinding efficiency of electroplated and vitrified bond wheels are initially investigated.
Electroplated tool can be characterized by a two component system: CBN and the bond material holding the abrasive. Once adhesion between the bond and the grit is secured the performance greatly depends on the grit. Vitrified bond wheel, on the other hand, corresponds to a three-component system: CBN abrasive, bond and porosity. Generally, the strength of grits needs to match the toughness of bond [5]. Additionally, adequate adhesion between the grit and the bond is required.
Figure 2 shows the grinding efficiency of CBN Abrasive A used in vitrified and electroplated wheels. Notice that the most significant difference is at low aggressiveness. Sharp and highly protruded abrasive on electroplated wheel requires less energy to cut material, i.e., the number of contact points is lower since the tool is fresh. Generally, vitrified bond wheel has larger contact area, e.g., dressing and bond effect. At high aggressiveness both curves start to merge to the minimum energy required to grind the workpiece material that is correlated with the material property.
The identified optimal aggressiveness for vitrified bond wheel is higher than for electroplated wheel. The reason is larger grit spacing in the lower concentration vitrified bond wheel which can as a result accommodate larger maximum chip thickness. According to these results it can be predicted that higher concentration and less porous vitrified bond grinding wheels would have optimal aggressiveness closer to electroplated one however higher initial specific grinding energy would be expected.

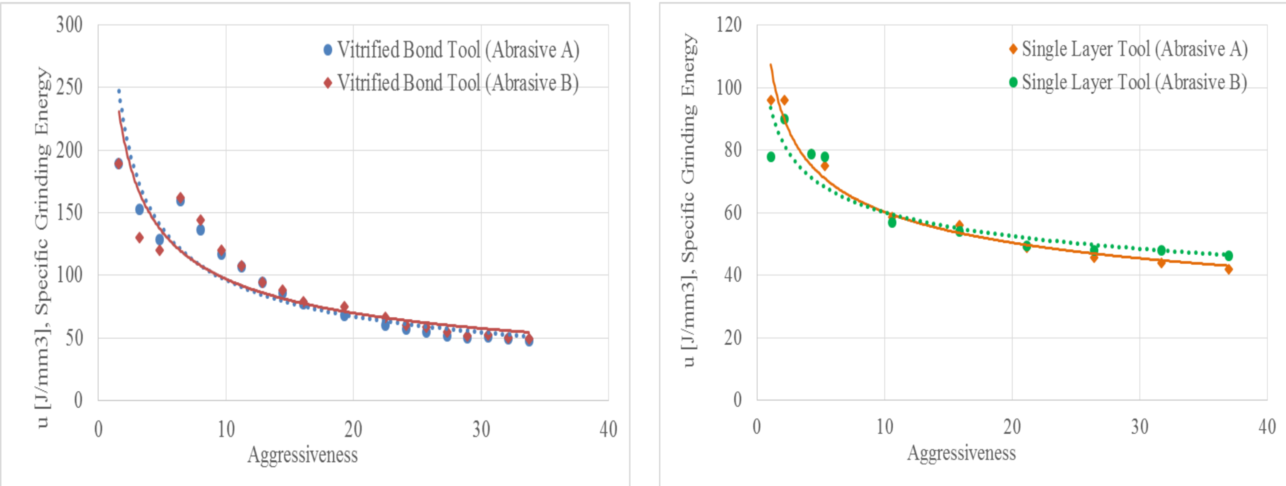


GRINDING PARAMETERS	ELECTROPLATED WHEEL
wheel speed	100m/s
depth of cut	1mm
specific material removal rate	1.6 – 60mm^3/mm s
aggressiveness	1 - 37
workpiece	M2 (62-64HRC)

GRINDING PARAMETERS	VITRIFIED BOND WHEEL
wheel speed	60m/s
depth of cut	1mm
specific material removal rate	1.6 - 35mm^3/mm s
aggressiveness	1 - 33
workpiece	M2 (62-64 HRC)

Figure 2: Grinding results using vitrified bond and electroplated wheels.

Vitrified bond and electroplated wheels with two different CBNs (CBN A and B) are now investigated. Similar grinding efficiency and identical optimal aggressiveness are shown in Figure 3 for both wheels in particular grinding set up, suggesting that the optimum grinding conditions is invariant with the grit type, shape and toughness. However, grinding wheel porosity, wheel type, grinding type and workpiece material have greater impact on the curve trend [10].



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GRINDING PARAMETERS	ELECTROPLATED WHEEL
wheel speed	100m/s
depth of cut	1mm
specific material removal rate	1.6 – 60mm^3/mm s
aggressiveness	1 - 37
workpiece	M2 (62-64HRC)

Figure 3: Grinding results using different abrasives in two grinding set-ups.

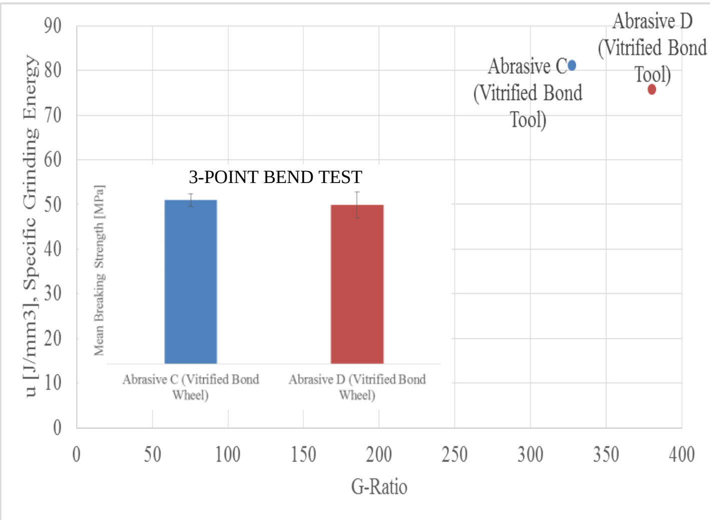
Wear Test

Optimal aggressiveness determined via the window of operation tests is used to evaluate the wheel-wear performance. Three criteria are normally used: forces, G-ratio, dressing interval.

Two examples using the same CBN abrasive type on electroplated and vitrified bond tool are presented in Figures 4 and 5.

The two dots on Figure 4 are presenting the G-Ratio of grinding wheel using two different grit types. Considering the previous investigation, wheel life (G-Ratio) and the specific grinding energy (u) can be considered invariante for both CBN abrasive tested. Similar performance could be assigned to similar adhesion between bond and grit which was determined using 3-point bend test (Figure 4) [11]. Sample bars, containing the same material as the testing wheel, have been used to measure the fracture strength while used in 3-point bending test. The measurements give an indication of the bond strength as well as adhesion between the grit and bond.

In the case of electroplated wheel, the performance difference between the same two abrasive types is significant. Although the abrasives have similar toughness, the structure is fundamentally different and that changes the breakdown mechanism. It is important to stress that effect of the grit properties on the wheel performance can be most clearly observed on electroplated wheel. The engineered particles that break down in a controlled way have shown impoved performance in this test, suggesting that the highest toughness is not always the solution.



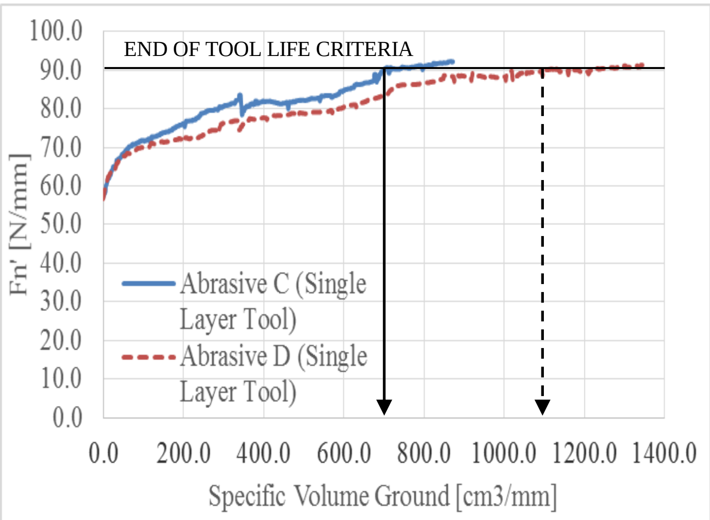
GRINDING PARAMETERS	VITRIFIED BOND WHEEL
wheel speed	60m/s
depth of cut	1mm
specific material removal rate	12mm^3/mm s
aggressiveness	12
workpiece	M2 (62-64HRC)

Abrasive $C_{toughness}$ ≈Abrasive $D_{toughness}$

Abrasive C_{TS} > Abrasive D_{TS}

Abrasive $A_{aspect\ rat}$ > Abrasive $D_{aspect\ rat}$

Figure 4: Tool life test using vitrified bond wheel at optimal aggressiveness.



GRINDING PARAMETERS	ELECTROPLATED WHEEL
wheel speed	100m/s
depth of cut	1mm
specific material removal rate	75mm^3/mm s
aggressiveness	40
workpiece	GGG70

Abrasive $C_{toughness}$ ≈Abrasive $D_{toughness}$

Abrasive C_{TS} > Abrasive D_{TS}

Abrasive $A_{aspect\ rat}$ > Abrasive $D_{aspect\ rat}$

Figure 5: Tool life test using electroplated wheel at optimal aggressiveness [12].

Conclusions

A series of grinding tests have been conducted using different grit types and bond systems. The results yield several observations:

(i) the optimum grinding conditions are invariant with the grit type, shape and toughness regardless of the bond system used;

(ii) grinding wheel porosity, wheel type, grinding type and workpiece material have greater effect on the specific grinding energy-aggressiveness curve;

(iii) the grit/bond adhesion is the key influencing parameter in vitrified bond wheel wear;

(iv) the effect of the grit properties is most clearly observed on single layer tools; using grits with high toughness is not always the solution.

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