High-production grinding with vitrified bond superabrasives Part 2: vDD technology for vitrified bond diamond dressers

A high-production grinding process can only be optimised if all the crucial factors in the system are analysed and improved. The contribution made by the grinding tool supplier is not limited only to the grinding tool itself, but can be significantly influenced by the selection and development of a matching dressing tool for conditioning [1]. In the first part of this series of articles, the method followed in the development of a new generation of CBN wheels, HPB technology [2], was described in detail. In order to optimise the overall grinding process on the tooling side, a matter for discussion is also however whether new approaches are possible in the selection of the dressing tool. Part 2 of this series is intended to provide an initial overview of the as yet new technology of vDD tools (vitrified Diamond Dressers) for dressing and then ventures to discuss the prospects of the potential of this group of tools. Report by **P. Beyer**.

The general standard in the conditioning of vitrified bond CBN grinding tools is the use of – if possible rotary – metal bond or electroplated diamond dressers. The dressers are as a rule characterised by very high wear-resistance. As a result, the dressers themselves must be resharpened regularly, or in the case of single-layer coated tools, they wear relatively quickly. In practice, for metal bond tools this means either that they have to be returned to the toolmaker for reconditioning, or at least the process has to be interrupted and the dresser has to be removed from the production machine for reconditioning. Electroplated tools have to be recoated by the manufacturer. Both options are relatively costly and time-consuming.

As an alternative, vitrified bonds have been tried occasionally. The tool life of the vitrified bond dressers being available on the market hitherto has generally been too short to be economical in series production. For a manufacturer in the specialist area of vitrified bonds the question is therefore whether this gap can be closed by suitably optimising the tool.

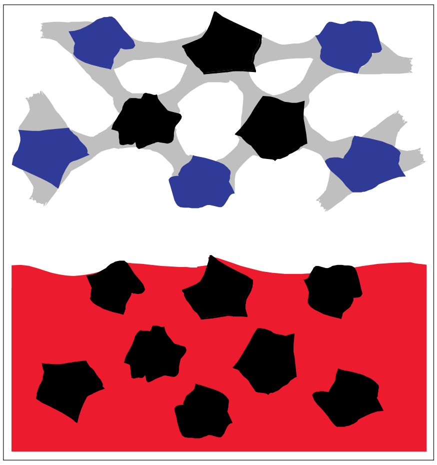

Fig 1 Structures of dressing tools – vDD, open, free-cutting (top); conventional, metal bond with little grit protrusion (bottom)

vDD dressers

The main differences in the structure of metal and vitrified matrix systems are shown in Fig 1. The dense structure of the metal bond can have only limited free-cutting properties. The open structure of the vitrified bond on the other hand offers much greater potential in this respect, but has disadvantages in terms of wear-resistance. The requirements for a vitrified bond dresser to be used economically are therefore:

- optimisation of grit retention forces,
- a free-cutting system, if possible without the need for manual resharpening,
- sufficient and process-reliable wear-resistance.

The factors to be optimised in their technical detail and their interactions are summarised by way of example in Fig 2. In particular, issues of grit properties, bond and porosity have been studied and put into practice.

Grit properties

The choice of crystal quality significantly influences the behaviour of the vitrified bond dresser. The following variables have to be taken into account when using diamond:

- the cutting and wear behaviour compared with CBN,
- surface structure and the 'anchoring' factor in the vitrified bond,
- thermal resistance to heat treatment during firing in an oxidising atmosphere.

Particular attention must be paid to the first of these factors, as this is where the main difference lies compared with the vitrified bond dressers having been available on the market so far. Both the wear characteristics of the diamond crystal itself as well as the influence on the morphology of the splintered CBN grit are the key for a well-functioning dresser. The last point massively limits the choice of crystal qualities from a manufacturing and technical point of view. While in a metal bond the matrix of the binder already acts as protection against oxidation, it is precisely the open vitrified structure that promotes the unfavourable supply of oxygen during the necessary firing process.

Bond

In the same way as in the development of bonds for CBN grinding tools, discussed in Part 1 of the previous issue of IDR, the bond is also relevant in dressing tools for retaining the individual diamond grains. In principle, however, factors that are considerably more critical have to be taken into account with some additional key parameters:

- wetting behaviour of the oxide vitrified bond on the non-oxide diamond grain,
- chemical reactivity,
- viscosity of the melt as a function of temperature,
- avoiding oxidation and graphitisation of the diamond grain.

The bonds that can be used for vitrified bond diamond tools consist essentially of the same group of metal oxides as in the bond systems that are suitable for CBN. Due to the characteristically lower affinity of diamond to the oxide vitrified bonds, considerably more complex conditions arise however for sufficient wetting by the bond or glass melt [3]. It is known that diamond reacts rapidly with carbide formers such as, among others, Fe, Co, Ni, Al, Si and B [4, 5]. However the wetting conditions with oxide melts are not very favourable with wetting angles greater than 100° [6]. In addition there is the critical oxidation behaviour having already been discussed and a development of gas associated with this, which is a further hindrance to the wetting process [7].

Even more critical is the temperature range that can be used for consolidation. Here the tool manufacturer is faced both with oxidation phenomena and possible (re-)graphitisation [4].

Depending on the grain size, i.e. the specific surface, and the type of diamond crystal, diamond already starts to react with oxygen at temperatures of around 500 °C to 700 °C, as shown below [4]:

$$C + O_2 \rightarrow CO_2 \qquad (1)$$

Consequently, vitrified bonds with a low melting point must be used, which in turn considerably limits the possibilities for varying the mechanical properties of the bond itself. The alternative use of an inert gas to avoid oxidation of the diamond is not possible due to the composition of the bond.

In vDD technology, therefore, by introducing a low-temperature consolidation process in connection with a wetting behaviour optimised with the selected addition of synthetic metal oxides, grit retention has been optimised to the extent that the diamond crystal types needed for successful dressing can be wetted and bonded.

Porosity

The porosity of the new generation of dressers that has been developed is somewhat less than that of the vitrified bond grinding tool. A balance must be found between wear-resistance and the ease with which the dresser itself can be conditioned. Compared with conventional metal bond dressers these are however highly porous structures. The texture of a selected vDD tool is shown in Fig 3.

Application examples

The vDD tools are now used in high volume production both as cup dressers on small turbines and also as wheel dressers with an inside or an outside diamond layer.

Fig 4 shows a dressing ring with an inside layer. Fig 5 shows an example of a tool with an outside layer.

By way of two application examples, Table 1 shows the practical successes of the new generation of diamond dressers used in production conditions compared with established tools.

The use of the first generation of vDD dressers has far exceeded expectations in practice. First prototypes have recently been transferred successfully into large batch production processes.

It was confirmed that there is no need for conditioning/resharpening which is absolutely essential in the case of metal bond dressing tools. As a result there is no time-consuming interruption of the machining process.

Also, because of the improved structure of the CBN grinding wheel after dressing, with vDD, the geometry of the workpiece (the taper of a bore) was improved and the tendency for heat generation was reduced.

The wear-resistance of modern vitrified dressers enables grinding wheel geometries to be profiled with great precision, provided that there is linear contact between both systems. At present, CNC-controlled dressing by interpolation of very fine profiles with only point contact still remains the domain of metal bond dressing tools. Future developments will enable the advantageous characteristics of vDD tools to be transferred to this area as well.

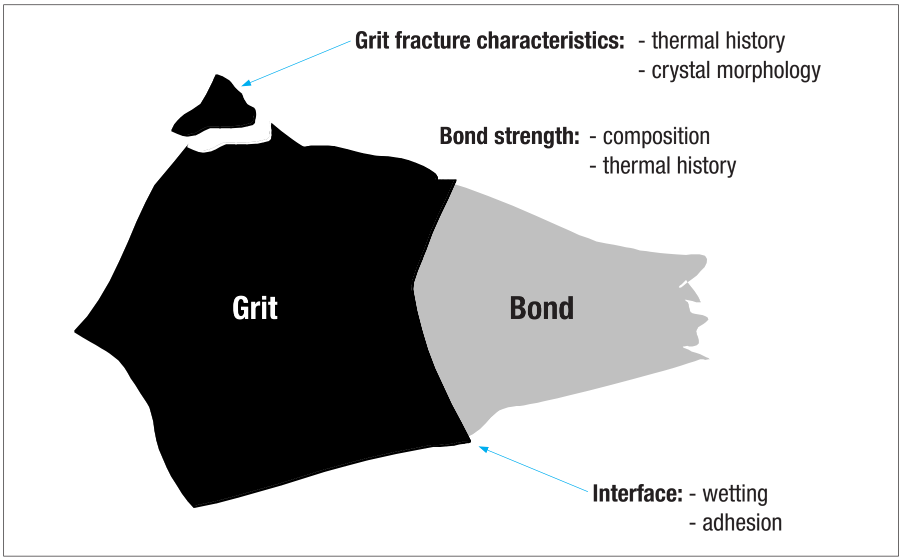

Fig 2 Parameters for optimising the vDD system

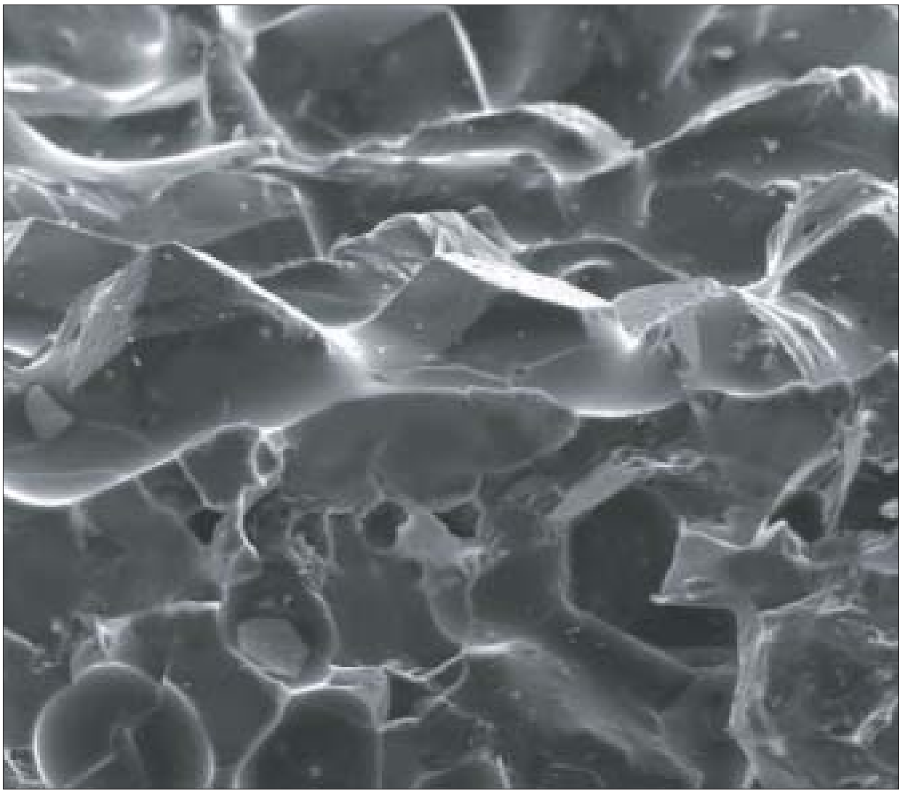

Fig 3 SEM of a vDD structure (200x). Structure with spherical pores (bottom half of the image) and a surface with optimally wetted grains and at the same time a high grit protrusion (top half of the image)

Future prospects

In the area of dressing tools the first step towards a new generation has already been made with the introduction of vDD dressers. The successful HPB (high performance bond) technology described in the previous issue of IDR is now being applied to diamond grinding tools. In the grinding of carbide and ceramics, and also in the machining of wafer materials such as Si, SiC, sapphire and GaAs, among others, new solutions will be presented shortly.

Analysing the development of the market shares of bond systems for CBN and diamond, in the case of CBN a continuing shift has been seen in favour of vitrified bonds in high-performance grinding for a long time.

Due to the technical hurdles referred to above in the use of diamond in vitrified bonds, this combination has a relatively small share of the market. If this optimisation can be achieved in the same way as with CBN, however, the great potential of these systems can easily be imagined. ◆

Fig 4 vDD tools for dressing internal cylindrical grinding wheels – internal layer

Application	Bore and valve seat	
Grinding tool	Swiss Master Vit CBN IGA 143° CB5-500-Q-9-260-200-V55-32	
Dressing tool	Swiss Master Vit DIA Dresser D11-170-P-8-280-X150-V88-39-2	
Machine	UVA	
Result	Meister vDD	Metal bond dresser
Tool life	110,000 parts	50,000 parts
Geometric deviation after changing grinding wheel	none	10 parts running-in
Workpiece geometry (taper)	< 1 µm	< 1 µm
Surface roughness R_z(component)	0.5 to 1 µm	0.6 to 1.1 µm

vDD application 1: Dressing internal cylindrical grinding wheels – dressing ring with inside coating

Application	Mini Lash Adjuster	
Grinding tool	Swiss Master HPB CBN IG CB21-230-R-9-185-175-V55-P71-31	
Dressing tool	Swiss Master Vit DIA Dresser DC D11-170-T-6-330-150-V86-39-2	
Machine	Voumard	
Result	Meister vDD	Metal bond dresser
Dressing interval	120	120
Sharpening interval of the dresser	– (self-sharpening)	weekly (in 3-shift operation)
Tool life	35,000 cycles	9,000 cycles (not process-reliable, smoothing of the CBN wheel)
Workpiece geometry (taper)	< 2 µm	up to 5 µm

vDD application 2: Dressing internal cylindrical grinding wheels – cup dresser

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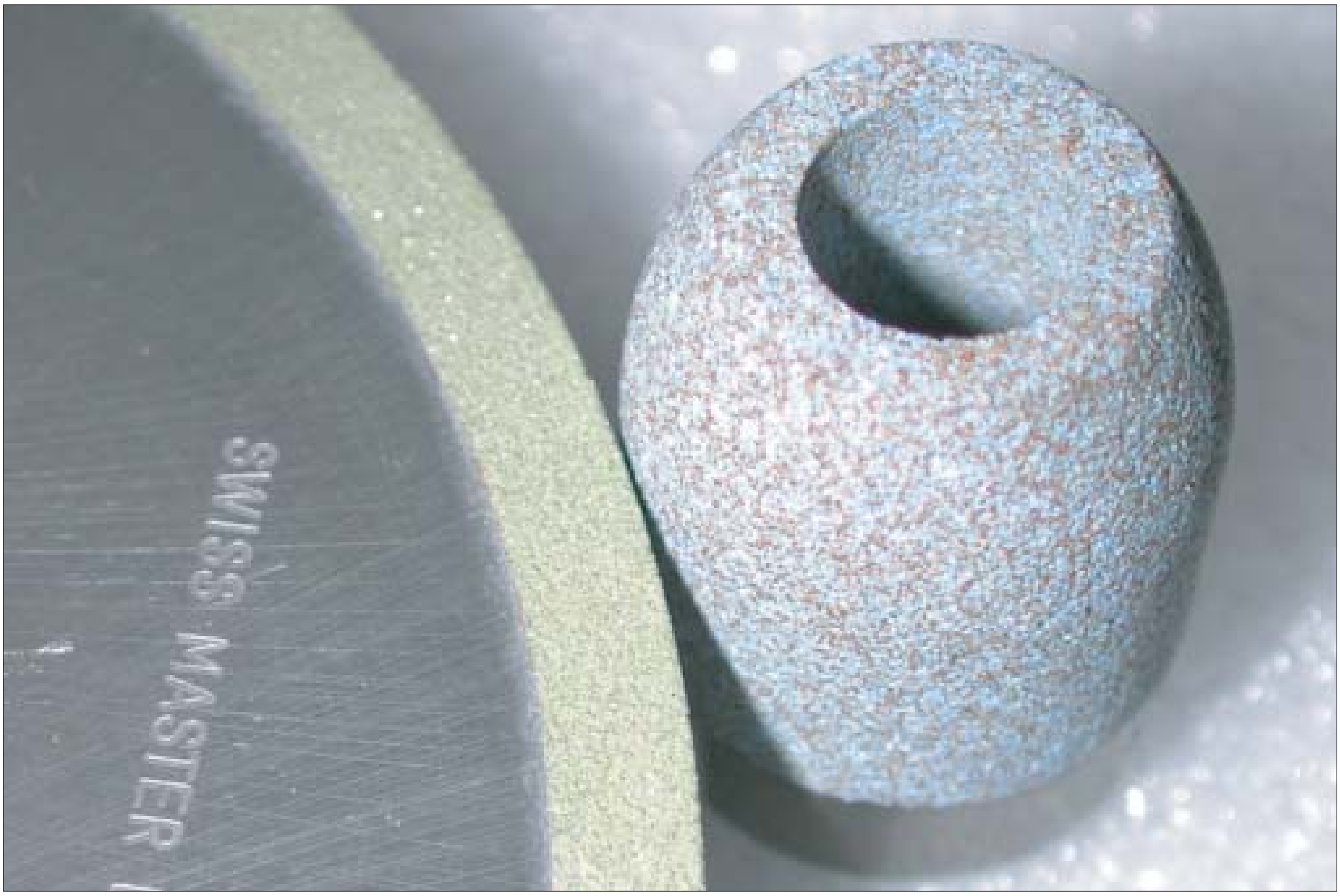

Fig 5 vDD tool for dressing internal cylindrical grinding wheels – external layer