Enhancing Element Six PcBN performance with a BALIQ coating from Oerlikon Balzers

Widening of the application window in which grades like DBS900 (H20-H35) and DHA650 (H10-H25) can be used, is achieved through coating developments

Introduction

Element Six specializes in the production of advanced polycrystalline cubic boron nitride (PcBN) materials (figure 1 & 2). Renowned for exceptional performance in non-ferrous machining applications, these are used across diverse industries. By supplying high-performance PcBN materials to leading toolmakers, Element Six enables its customers to challenge effectively in highly competitive markets. The demanding nature of machining applications requires PcBN materials to exhibit exceptional resistance to both thermal and mechanical failure.

Oerlikon Balzers is a world-leading provider of surface technologies, develops solutions and equipment and offers services to considerably improve the efficiency and longevity of tools and precision components for the metal and polymer processing industries.

The challenge

While high-content grades exhibit exceptional toughness, they share a common drawback. Certain machining applications demand not only the extreme toughness of the high cBN content, but also superior chemical wear resistance. This dilemma presents toolmakers and end users with a choice between employing two different tools, incurring higher costs, or seeking alternative approaches to meet the specific requirements of this machining segment.

Partnership

To address this challenge, Element Six and Oerlikon Balzers, a globally renowned provider of surface technologies, established a collaborative partnership. The objective of this collaboration was to develop unique coatings for Element Six's DHA650 and DBS900 materials, enhancing their chemical wear protection.

Figure 1: Full round disc of solid PcBN

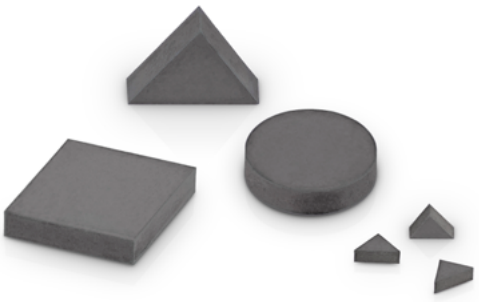

Figure 2: Solid PcBN segments for ISO insert manufacture

Resilient PcBN variant development

Leveraging extensive expertise and commitment to innovation, Element Six continues to develop highly resilient PcBN grades, such as Purecut™ DHA650 and DBS900.

It is worth noting that the cubic boron nitride (cBN) content of PcBN materials typically ranges from 40% to 95%, tailored to meet specific performance requirements. Lower cBN content (45%) enhances chemical wear resistance, while higher content, like that of DBS900 (90%), enhances overall toughness. Consequently, toolmakers face the challenge of balancing these factors to safeguard the tool when confronted with imbalanced machining demands. For example; machining across and down the face of a gear (figure 3) where toughness is required for the interrupted section, but chemical wear resistance is need on the face.

Figure 3: Example of hardened steel gear requiring machining across its face and teeth

Wider application windows

The testing of these coated grades, reviewed later in this document, revealed two additional benefits on top of improved tool life. Coatings offer both DHA650 and DBS900 the ability to be used in much wider application windows than previously available, see figure 4. Combined with increasing the maximum permissible cutting speed each can be used at. These benefits greatly improve the grades flexibility to toolmakers and end users.

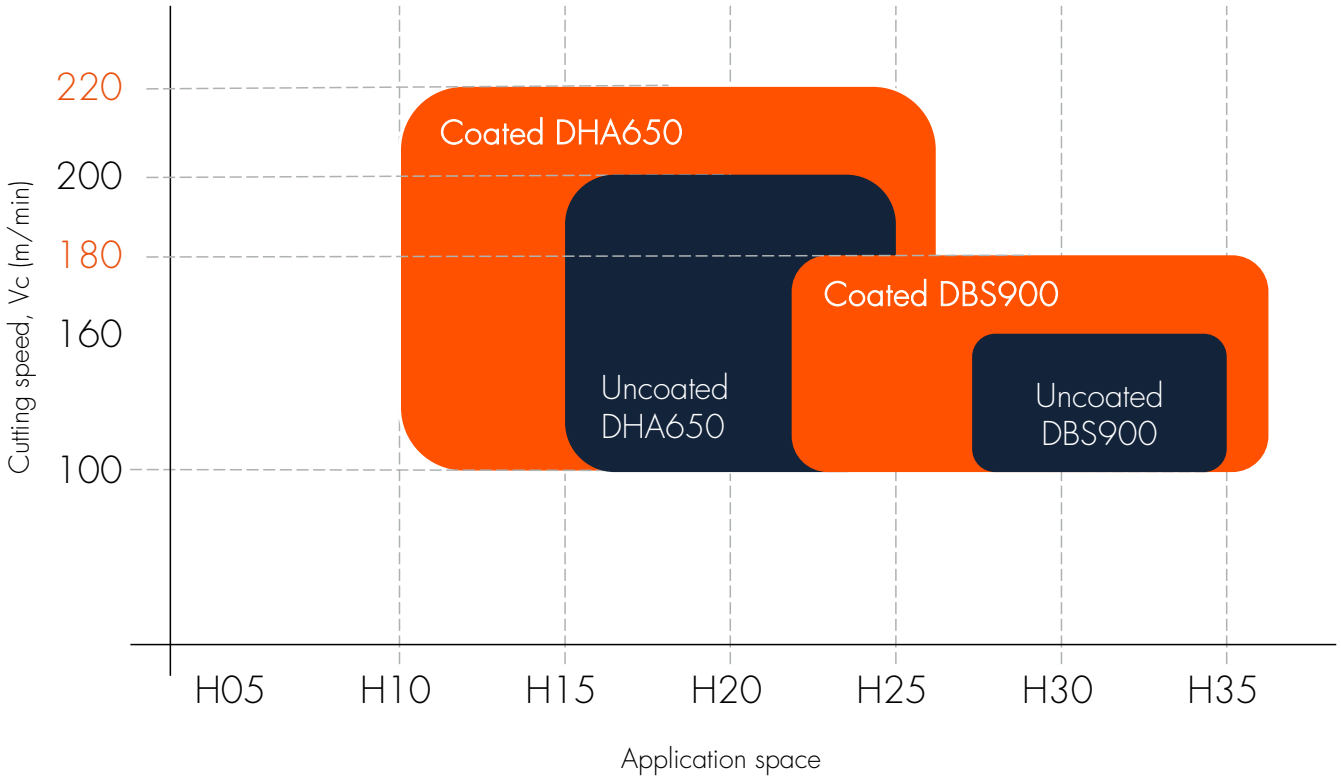

Figure 4: Diagram showing how coated DHA650 and DBS900 offer wider application windows and also increased maximum permissible cutting speeds

Elements of tool performance

In order to ensure optimal tool performance, three core areas of tool making must be addressed:

- Substrate material (PcBN)
- Edge preparation
- Machining conditions

In addition, a coating can be applied to enhance performance (figure 5). Coatings are typically applied to enhance the chemical wear resistance of a substrate. The coating adds an additional barrier between the workpiece and tool substrate which inhibits the chemical reaction between the two. Incorrect selection or application of any of these four parameters can lead to unsatisfactory tool performance.

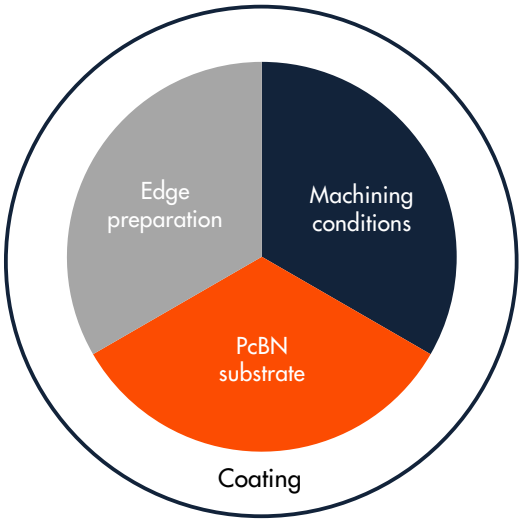

Figure 5: Representation of the application of a cutting tool, detailing the core performance elements surrounded by the enhancing coating

Development and testing

Throughout the collaborative development cycle, numerous coating technologies were tested, both for their compatibility with the PcBN substrate and for the final tool performance. Element Six conducted multiple internal standardised tests (see table 1) in order to both test the ultimate performance and how wide the application window could reach for each PcBN grade.

ISO513 H scale	H05 (continuous)	H15 (lightly interrupted)	H25 (heavily interrupted)	H35 (extremely interrupted/milling)
Grades tested	DHA650 & DBS900	DBS900	DHA650	DBS900
Cutting Speed	200 m/min	140 m/min	180 m/min	150 m/min
Feed	0.1 mm/rev	0.11 mm/rev	0.1 mm/rev	0.1 mm/rev
Depth of cut	0.15 mm	0.15 mm	0.15 mm	0.3 mm
Coolant	No	No	No	No
Workpiece	SAE8620 Steel	SAE8620 Steel	SAE8620 Steel	SAE8620 Steel
Insert geometry	CNGA120408 1525 ~Hone17μm	CNGA120408 1525 ~Hone17μm	CNGA120408 1525 ~Hone17μm	CNGA120408 1525 ~Hone17μm

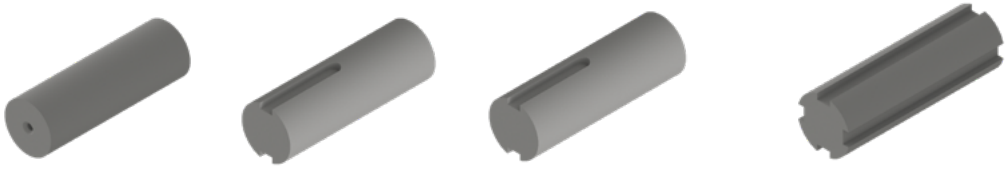

Table 1: Cutting parameters tested and example representation of the workpiece geometry tested

DBS900 coating development

The challenge

Being a high content PcBN material, DBS900 can suffer from increased chemical wear during continuous cutting durations.

The solution

Oerlikon Balzers developed a PVD coating based on BALIQ ALTINOS, with improved adhesion to the substrate, providing enhanced chemical wear resistance to DBS900.
Element Six conducted standard cutting trials in continuous (H05), heavily interrupted (H25) and extremely interrupted (H35) applications spaces (see table 1 for details).

The results

The performance of DBS900 is significantly improved with an almost 40% increase in heavily interrupted machining (figure 6) and a significant improvement in the chemical wear resistance. This coating exhibits superior adhesion to the substrate (figure 7), even under extreme loading and impact conditions, while providing enhanced protection to the cutting edge during high-temperature machining operations. This has effectively widened DBS900's application window at the highly interrupted end of the scale and made it more resistant to workpieces with continuous portions.

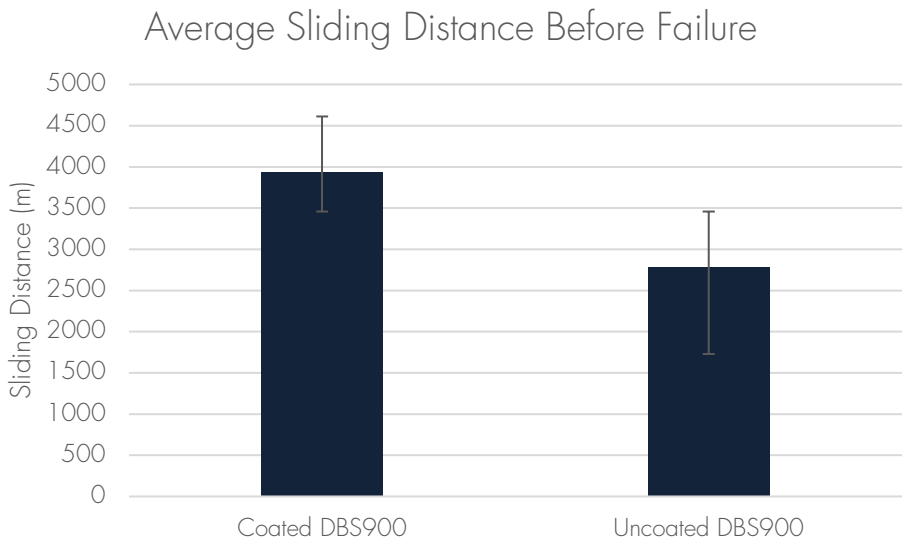

Figure 6: Graph showing the average, and minimum and maximum error bars, cutting distance to failure of coated (left) and uncoated (right) DBS900 in an H35 application test

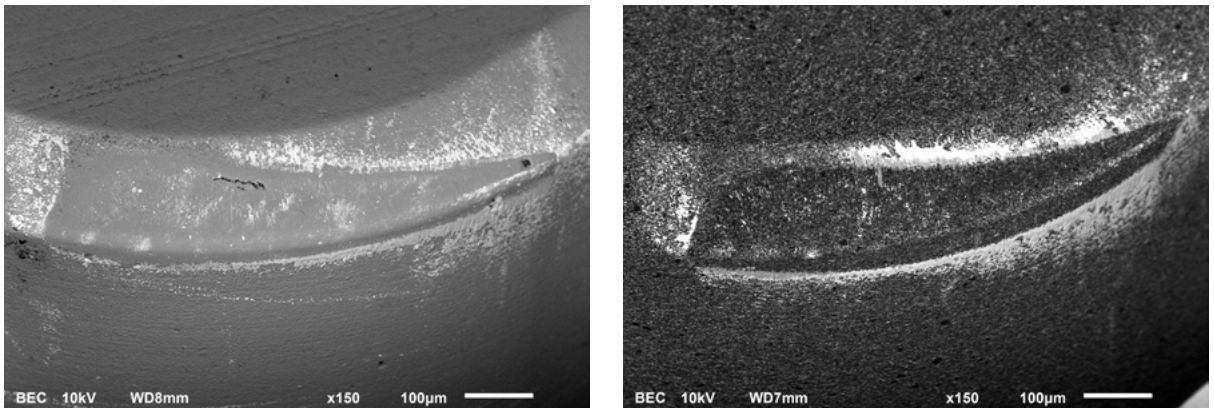

Figure 7: Scanning Electron Microscopy (SEM) images of DBS900 cutting tools, coated (left) and uncoated (right), after machining 500m distance in an H35 application test

Purecut™ DHA650 coating development

The challenge

With the development of a new PcBN manufacturing platform by Element Six, Purecut™, an innovative coating solution was required for use with Purecut™ grades, such as DHA650.

The solution

Oerlikon Balzers evaluated multiple coating options specifically for DHA650, arriving at a solution based on its BALIQ ALTINOS coating. Element Six conducted standard cutting trials in continuous (H05) and heavily interrupted (H25) application spaces (see table 1 for details).

The results

Element Six lab testing has demonstrated good coating adhesion (figure 9), extended tool life (figure 8 left) and reduced wear in both interrupted and continuous turning using coated DHA650. The righthand graph in figure 8 tracks the workpiece surface roughness throughout the life of both the coated and uncoated tools. Here it can be seen that the coated DHA650 tool provides a significant roughness improvement. The testing in H05 showed reduced crater wear, effectively increasing the break-in period of the tool, thereby improving the tools stability and performance for longer.

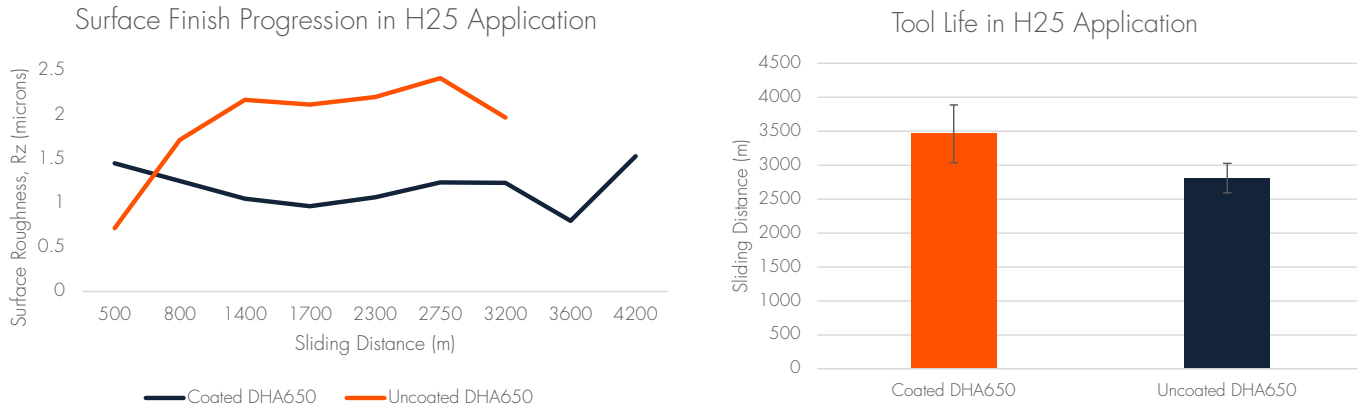

Figure 8: Wear progression of coated and uncoated DHA650 in an H25 continuous application test

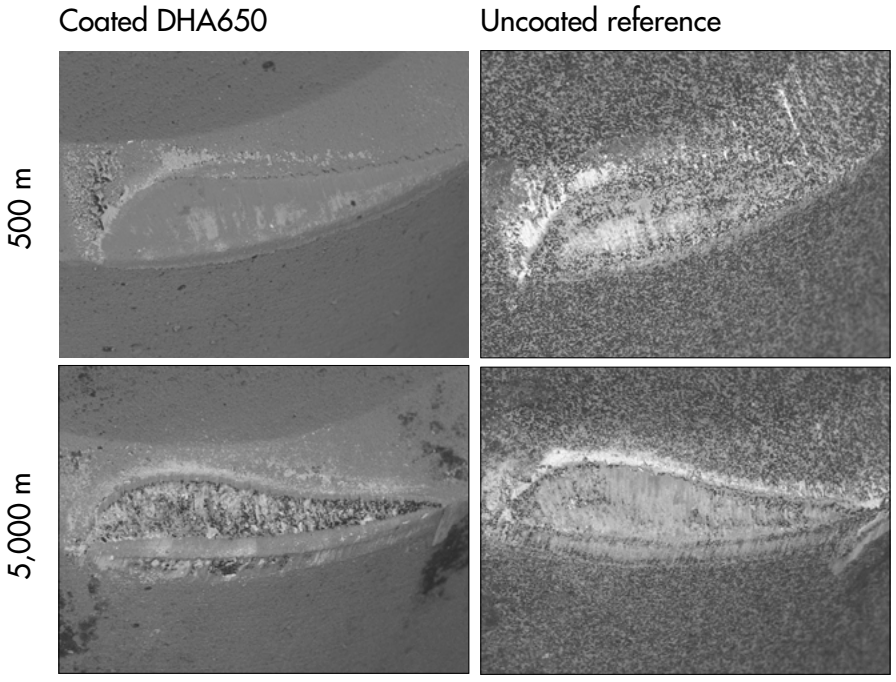

Figure 9: Scanning electron microscopy (SEM) images of coated and uncoated tools at the start of the test and during the test. Bottom left image shows the coating still adhered well to the DHA650 substrate

Development conclusion

The collaborative efforts between Element Six and Oerlikon Balzers have led to significant advancements in enhancing the performance and application range of both DHA650 and DBS900 PcBN materials. By addressing the trade-off between toughness and chemical wear resistance, toolmakers can now benefit from a single tool solution, offering improved efficiency and reduced costs.

About Element Six

Element Six (E6), part of the De Beers Group, designs, develops and produces synthetic diamond and other supermaterials, and operates worldwide with primary manufacturing facilities in Germany, Ireland, South Africa, the UK and US.

E6 solutions are used in applications such as cutting, grinding, drilling, shearing and polishing, while the extreme properties of synthetic diamond beyond hardness are opening up new applications in a wide array of industries such as optics, power transmission, water treatment, semiconductors and sensors.

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About Oerlikon Balzers

Oerlikon Balzers is a world-leading provider of surface technologies, develops solutions and equipment and offers services to considerably improve the efficiency and longevity of tools and precision components for the metal and polymer processing industries.

With more than 110 coating centers in 35 countries in Europe, North and South America and Asia, Oerlikon Balzers operates a dynamically growing network. Together with Oerlikon Metco and Oerlikon AM, Oerlikon Balzers is part of the Surface Solutions Division of the Swiss-based Oerlikon Group (SIX: OERL).

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