Vacuum brazing of hard materials including cBN and diamond

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1. Abstract

Vacuum brazing is one of the most versatile joining techniques. Design engineers are free to choose from a broad range of materials, to combine dissimilar materials and their properties. Even "exotic" material combinations like titanium and hard metal can be realized by vacuum brazing. Besides joining of hard materials for structural components brazing of abrasive and cutting tools is frequently used. Special brazing processes and sophisticated grit placement techniques are used to manufacture abrasive tools with a "designed" grit distribution according to the application requirements. Direct brazing of pure cBN to tool carriers enables fabrication of indexable inserts with substantial benefits for machining processes which operate at elevated temperatures. Potential of vacuum brazing will be documented by components and tools being realized over the past years by a toll brazing company.

2. Introduction

Despite a tremendous development in near-net-shape techniques most technical components are manufactured by machining. Besides drilling, turning and milling which use a geometric defined cutting edge grinding with undefined cutting edges has gained increasing importance. High speed cutting, machining of hardened steels and the use of small amounts of coolants or even dry cutting result in high demands on the entire tooling concept with consequences for the cutting or grinding material. They are in direct contact with the workpiece and are faced with extremely high mechanical, thermal and chemical loads.

Vacuum brazing offers new opportunities to join all hard and superhard materials. Combined with sophisticated grit placement techniques design engineers can create tools even with complex shapes. Vacuum brazed indexable inserts with solid cBN exhibit outstanding strength and are used for machining processes operating at elevated temperatures.

3. Brazing Process

Non-metallized superhards can be brazed by the so called active or direct brazing process. Brazing alloys contain reactive metals like titanium which form a reaction layer at the interface (fig. 1). Commercial available brazing alloys are based on the silver-copper, silver-copper-indium or copper-tin system and commonly used for ceramic-metal-joints.

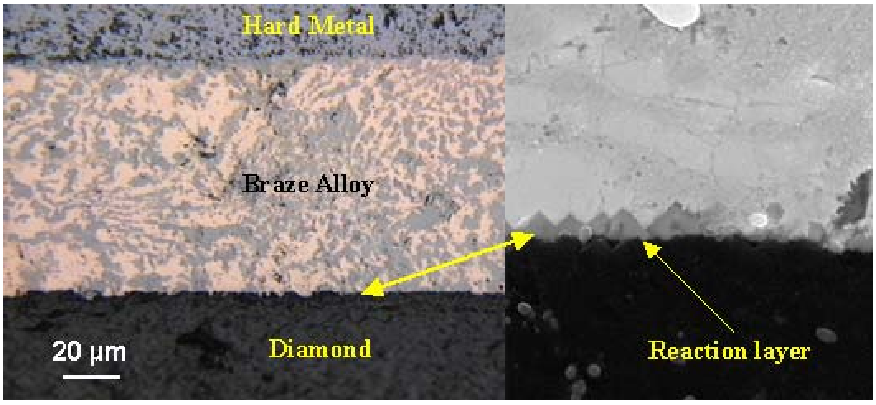


Figure 1: Micrograph of a vacuum brazed PCD-Hard Metal joint
Braze Alloy: CuSnTi; Brazing Temperature: 920-980°C

Brazing process is performed in an all-metal hot-zone furnace with a vacuum level better than 10^{-4}mbar and a temperature range between 920 and 960°C.

Diamonds also can be brazed with nickel alloys containing chromium which acts as an "active metal" [1]. High brazing temperatures of about 1.000 °C are required. Under such conditions contact surfaces will be attacked severely which often result in decomposition and crack formation in the diamond.

4. Abrasive Tools

Tools with a single layer of abrasive grits are produced mainly by electroplating. Grits are embedded within a nickel-alloy matrix and only fixed mechanically. Grit protrusion is less than 40-50% of average grit size. During a grinding operation matrix wear can result in early grit pull-out and short service times. Vacuum brazed grinding tools with diamond or cBN grits are promising alternatives. Different brazing alloys and modification of the base alloys together with adapted brazing parameters allow control of chemical interaction and bonding strength.

For high removal rates and long service times, two design objectives have to be achieved:

- grit protrusion to ensure sufficient cutting depth
- grit clearance to remove chipping material and to avoid blocking.

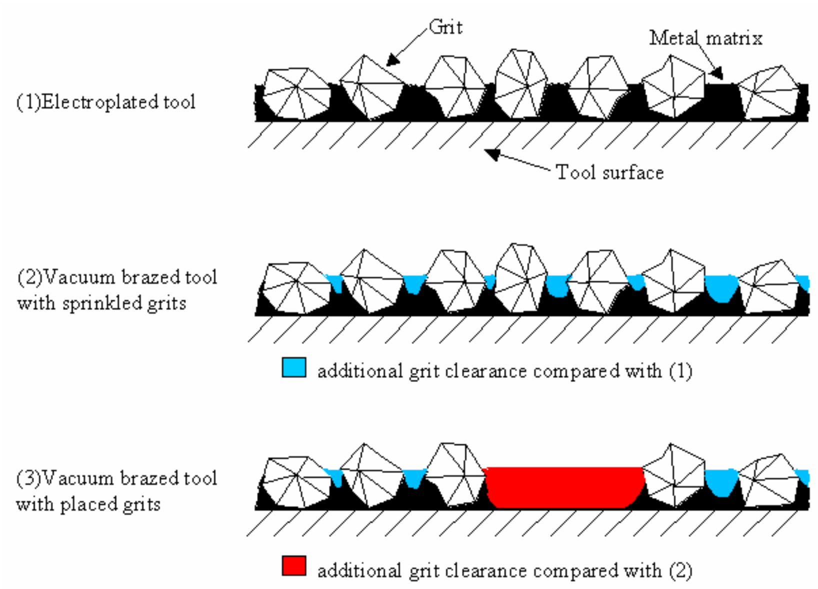


Figure 2: Grit clearance by different production methods for abrasive tools

Within the framework of a national research project in Switzerland a new technique has been developed to place grits with a controlled distribution [2, 3]. Combined with vacuum brazing abrasive tools can be fabricated with designed grit protrusion and clearance (fig. 2).

Practically the whole production process can be subdivided into 3 steps:

1. cleaning and preparation of tool carrier
2. setting of glue spots and sprinkling of grits
3. braze alloy application and brazing

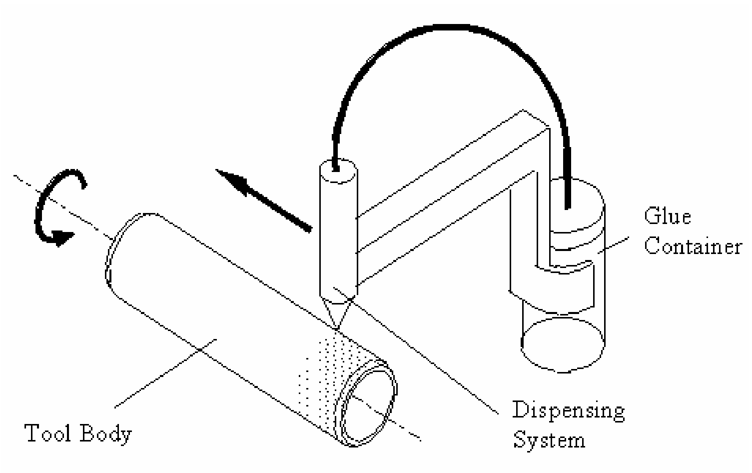


Figure 3: Schematic view new of grit placement technique

Step 2 is the most innovative one. By a special dispensing system glue drops are "fired" to the tool surface (fig 3). Afterwards grits are sprinkled over the surface and stick where the glue spots are located. Finally a braze alloy slurry is brushed or sprayed over the grits. The amount of applied braze alloy gives desired grit embedment after brazing.

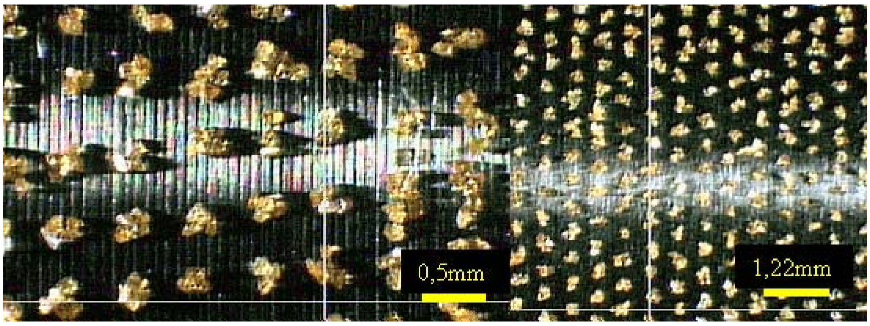
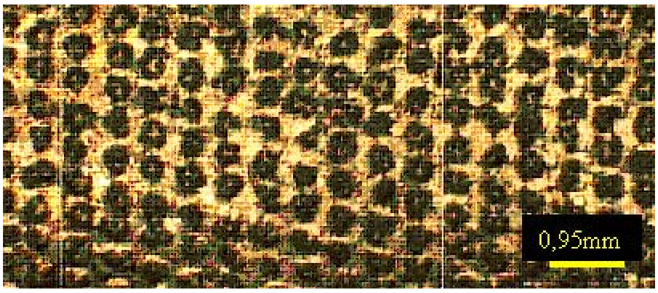


Fig. 4a shows a section of a honing tool ϕ_a11x50mm after placement of cBN grits B107 and fig. 4b same tool after vacuum brazing.

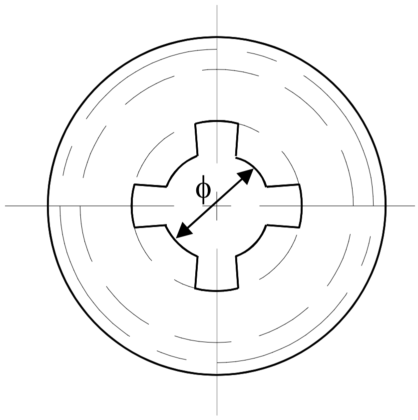
Figure 4a: Honing tool after cBN grit placement, grit size B107



To evaluate the performance of new cBN honing tools compared to electroplated tools they were tested in a real production process. The inner diameter of a gear wheel was machined as specified below.

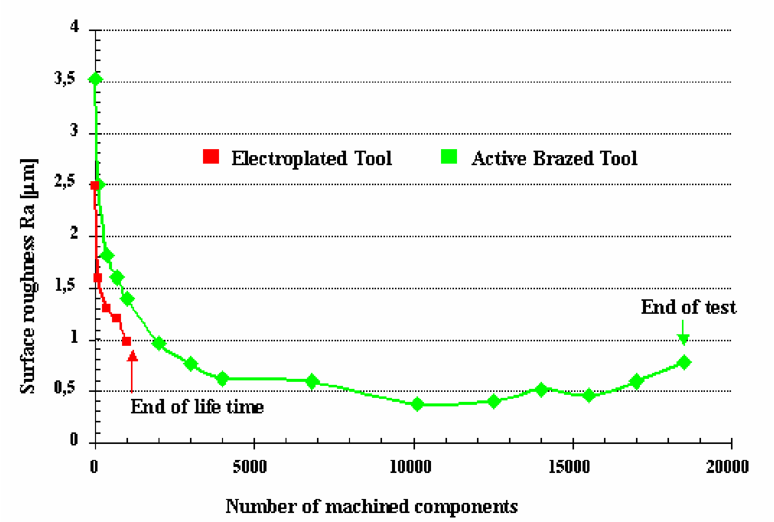
Figure 4b: Honing tool as vacuum brazed

Steel: 16MnCr5 (SAE J 1249)
Hardness: 740±80 HV10
Inner diameter before honing: ϕ11,92±0,02mm
Inner diameter after honing: $\phi 12^{F7}$ (+0,016mm - +0,034mm)
Diameter increase: 0,09mm



Honing machine: SUNNEN 1806
Revolution: 2.000 min^{-1}
Feed: 3m/min
Coolant: Vulcolap ISO10

A package of 10 wheels was machined in one process. With electroplated tools diameter enlargement is done in 3 operation steps, two with a diameter increase of 0,04mm each followed by a final operation with 0,01mm. Using vacuum brazed tools one step could be eliminated by running one operation with 0,08mm and one with 0,01mm, which cuts down total operation time by 33%.



More impressive is performance improvement in service time (fig. 5). Electroplated tools enable machining of about 2.000 parts whereas vacuum brazed tools can be used for machining up to 20.000 parts.

Figure 5: Comparison of electroplated and vacuum brazed honing tools

5. Cutting Tools

If indexable inserts with diamond or cBN tips are vacuum brazed selection of braze alloy is important and determined by two factors mainly:

- residual stresses in the brazed joint
- service conditions during operation

Residual stresses are induced during cooling by the mismatch of different expansion behavior (CTE α and Young's modulus E) between tool carrier and superhard material. To minimize residual stresses this mismatch should be as small as possible. From that point of view a combination of cBN and hardmetal is excellent. Fig. 6 shows a micrograph of a vacuum brazed joint of cBN and hardmetal with a reaction layer formation being known from active brazed ceramic-metal joints.

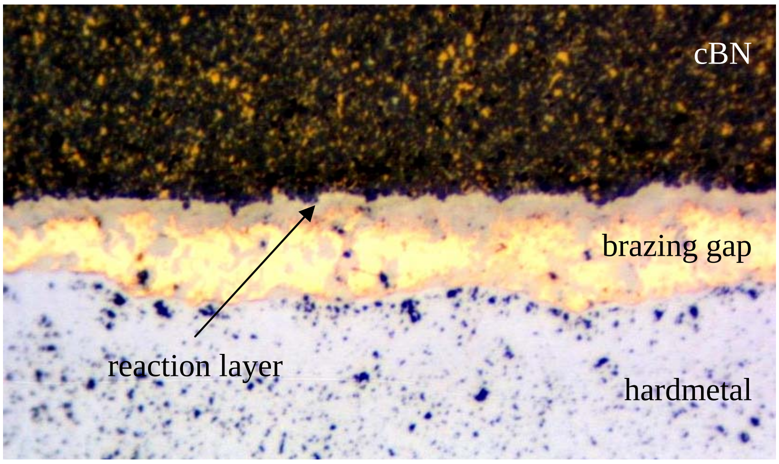


Figure 6: Micrograph of vacuum brazed cBN-hardmetal joint
Braze Alloy: CuSnTi; Brazing Temperature: 920-980°C

To control residual stresses solidus temperature of the braze alloy should be as low and its plasticity as high as possible. However, demanding machining operations like high speed cutting or turning without coolant result in high mechanical and thermal loads on the cutting insert. To avoid softening and failure of the joint solidus temperature and mechanical strength of the braze alloy needs to be high.

If diamond or cBN is used as a solid body as indicated in fig. 7 indexable inserts with multiple cutting edges can be utilized.

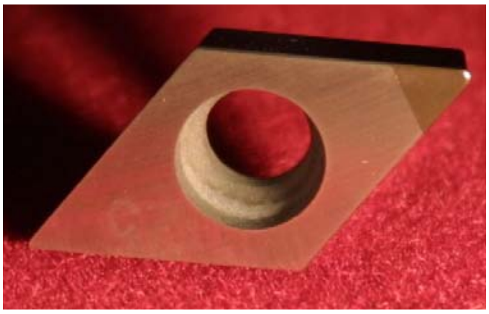


Figure 7: Vacuum brazed cBN indexable insert with four cutting edges

6. Summary

The need to improve cutting and grinding operations as well as the use of new materials and component design with complex shapes have forced the utilization of tools with diamond and cBN as cutting or grinding material. Brazing is a flexible method to attach superhard grits or tips to the tool carrier.

Conventional torch or induction brazing of indexable inserts with hardmetal backed PCD (polycrystalline diamond) or cBN has been routinely employed for a long time. Even brazing of coated grits has been introduced into practice already. Combining vacuum brazing with active braze alloys offer new opportunities in selection of superhard materials and tool design. Diamond and cBN can be joined without prior metallization to a broad range of tool carrier materials.

Grinding tools can be made where grit clearance, distribution and embedment is designed to the need of the specific application. Excellent free cutting abilities, high bond strengths and nearly no limitation in tool design classifies application properties of vacuum brazed between sintered and electroplated abrasive tools. Active brazing of superhards with a defined cutting edge without a hardmetal back allows the use of braze alloys with higher melting points and enables improved bonding strengths at elevated service temperatures.

7. References

[1] N.N.: Industrie Diamanten Rundschau (IDR) 1/1999, 33, 72-76

[2] G. Burkhard, B. Zigerlig, M. Boretius: Industrie Diamanten Rundschau (IDR) 2/2002, 36, 96-102

[3] European patent EP 1 208 945 B1, "Verfahren zum Herstellen von abrasiven Werkzeugen"