Wear protection coatings generated by brazing, sintering and heat treatment in vacuum

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Kurzfassung

Mittels Vakuumlöten werden Komponenten mit unterschiedlichen Verschleisseigenschaften stoffschlüssig miteinander kombiniert, wie z.B. Hochleistungskeramiken oder sogar Diamant mit Stahl. Entwickler und Konstrukteure haben die Möglichkeit, Materialien mit spezifischen Verschleisseigenschaften nur dort einzusetzen wo sie tatsächlich benötigt werden oder sogar neue Funktionalitäten zu schaffen. Durch die löttechnische Applizierung von flexiblen Matten, die aus einem Lotpulver und Hartpartikeln bestehen, auf die Bauteiloberfläche, lassen sich Verschleissschutzschichten mit Dicken von 0,5 bis einige Millimeter herstellen. Das Vakuumsintern von Kompositmaterialien ermöglicht sehr dicke Schichten, die sich durch einen hohen Hartstoffgehalt und hartmetallähnlichen Eigenschaften auszeichnen. Der einzigartige ODH-Prozess (Oxygen Diffusion Hardening) kann den Verschleisswiderstand von Titanwerkstoffen erheblich verbessern. Die Oberflächenhärte von Titan Grade 5 kann bis zu 1.000 HV erreichen, was nahezu dem Dreifachen der Kernhärte entspricht.

Schlüsselwörter

Vakuumlöten, Sintern, Wärmebehandlung, Härten, Beschichtungen, Titan, Verschleissschutz, Hartstoffe

Abstract

By vacuum brazing solid components with adapted material properties can be joined to each other, e.g. ceramic or even diamond to steel. Design engineers have the flexibility to use specific wear resistant materials only where needed and to create new or improved functionality. Applying prefabricated tapes, consisting of a braze alloy and hard particles, to a component surface, a wear resistant coating can be established with thicknesses from 0.5 up to few mm.

By vacuum sintering of composite materials coating thickness can be further increased with a very high content and equal distribution of hard phases, resulting in wear resistance properties close to hard metals.

The unique ODH process, which means Oxygen Diffusion Hardening, can improve the wear resistance of titanium alloys significantly. Surface hardness of ODH treated Titanium Grade 5 can reach up to 1.000 HV which is almost 3 times the hardness of the bulk material.

Keywords

Vacuum brazing, sintering, heat treatment, hardening, coatings, Titanium, wear protection, hard materials

1 Introduction

Heat treatment processes performed in vacuum give the opportunity to use different technologies for generating wear resistant coatings or diffusion layers on a broad range of component materials. Thin PVD or CVD as well as very thick surface welded coatings are very popular to design tribological performance of surfaces. Presented complementary technologies brazing, sintering and heat treatment enable coating thicknesses starting from 0,02 mm up to 20 mm or even more.

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2 Wear protection by brazed composites

Vacuum brazing is predestinated to implement a modular design approach. Complex shaped parts can be generated by joining simple, inexpensive semi-finished products to each other. Even combinations of very thin-walled and sturdy components, which are difficult to weld, are possible. Moreover materials even with a significant difference in mechanical and/or physical properties can be joined. For instance electrical or thermal isolators can be combined with materials possessing a high electrical or thermal conductivity [1]. This strategy can be applied to wear applications too, where very hard materials are metallurgical connected to softer ones. **Figure 1** shows a steel clamping jaw with a grip coat consisting of brazed hard metal grits. Besides wear protection the rough tool surface enables reliable clamping of components made of less stiff materials like aluminium and titanium during machining.

A similar property combination is demonstrated in **Figure 2** showing the cross section of a cubic boron nitride (cBN) composite layer brazed to a steel component [2]. **Figure 3** on top shows a dosage piston for food industry consisting of an alumina cylinder, being wear resistant and chemically inert, directly brazed to a steel connector in which afterwards the thread for the drive is machined.

3 Wear protection by brazed coatings

With the so called tape technology flexible pads can be manufactured consisting of a metal or ceramic powder and a polymer binder (**Figure 4**). Shaping by stamping or cutting is easy, adapting itself to curved component surfaces [3, 4].

At first a tape with hard particles is placed on the component area to be coated, then a braze filler metal tape is applied on top. The whole assembly is introduced into a brazing furnace. When heating up the tape binder decomposes and evaporates leaving a skeleton of hard and filler metal powder particles. At brazing temperature, the filler metal melts, infiltrates the hard metal skeleton and creates a metallurgical bond to the component surface (**Figure 5**).

By this simultaneous infiltration and brazing process wear resistant coatings with high hard particle content up to 70 vol.-%, homogeneous particle distribution and a thickness from 0.7 up to few mm can be created. Depending on the nature of the hard particles coating hard-

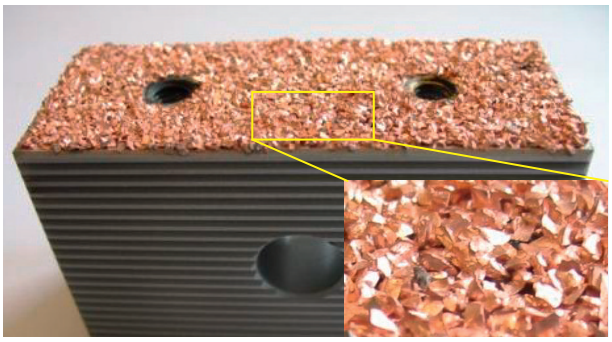

Figure 1: *Clamping tool with brazed grip coat*

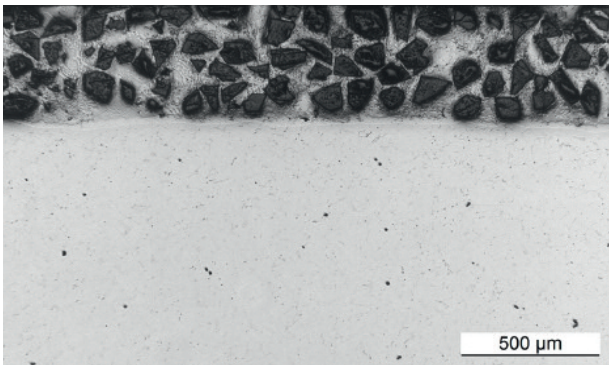

Figure 2: *Vacuum brazed cBN-hard facing alloy composite*

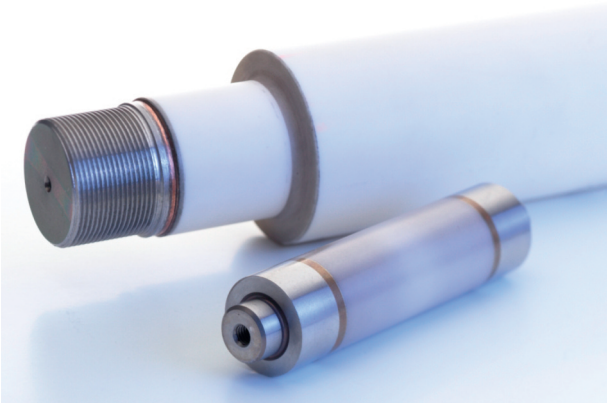

Figure 3: *Active or direct brazed ceramic-metal-joints*

Figure 4: *BrazeCoat-M® tapes*

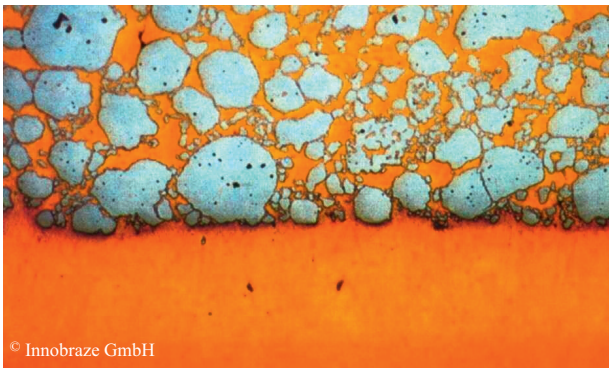

Figure 5: *Microstructure of BrazeCoat-M® after brazing*

Figure 6: *BodyClad® hard facing on farming ploughshare*

Figure 7: Microstructure of BrazeCoat-S® after brazing

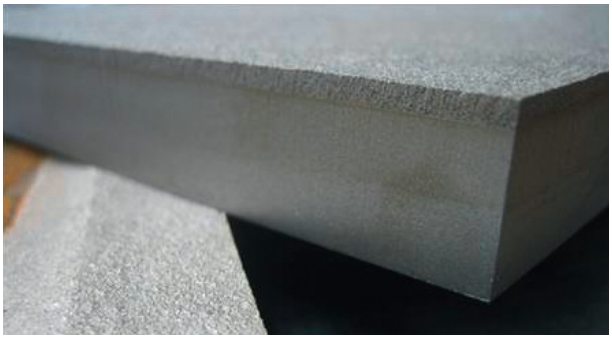

Figure 9: Vacuum sintered composite coating (SWP)

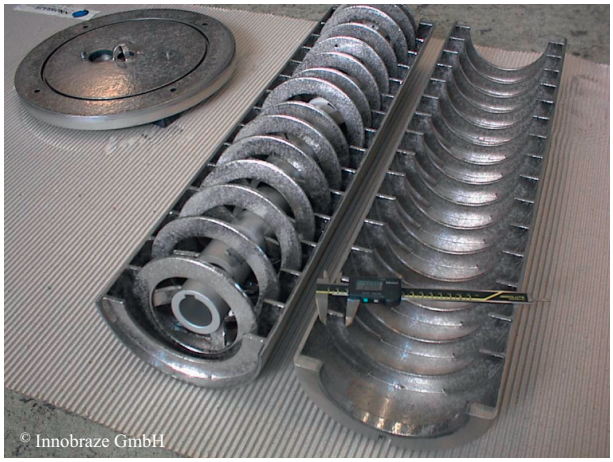

Figure 8: Disc mill components coated by BrazeCoat-S®

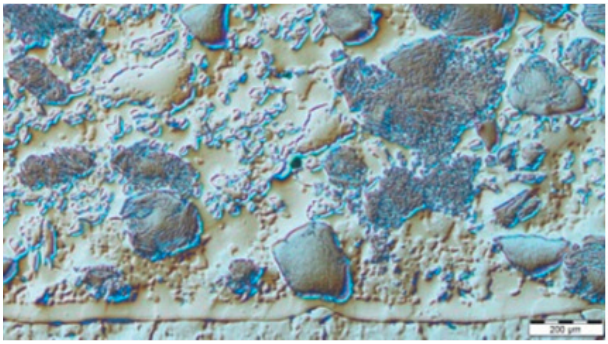

Figure 10: Cross-section of a vacuum sintered hard coating

Figure 11: Slides coated by SWP after warm forming

ness up to 70 HRC can be achieved. Such coatings prove itself in applications with heavy abrasive wear attack as experienced with ploughshares for farming equipment (**Figure 6**).

Even for lower coating thicknesses, in the range of 0.05 - 0.5 mm, brazing can be applied. A suspension consisting of hard and braze filler metal powder is sprayed to the component surface, air dried and finally densified by a brazing process. Resulting coatings are dense, smooth, with very fine dispersed hard particles and a coating hardness up to 65 HRC (**Figure 7**). This procedure is suited to coat even complex shaped parts as demonstrated with components for disc mills (**Figure 8**).

4 Wear protection by sintered coatings

SWP, an abbreviation for **S**intered **W**ear **P**arts, is a technique to manufacture wear resistant semi-finished products as well as coatings. A mixture of carbide and hardfacing alloy powder is placed on a steel surface and consolidated by a vacuum sintering process. The result is a very dense, smooth coating with a thickness up to 4 mm (**Figure 9**).

Compared to surface welding a very uniform hard particle distribution is observed. Within the same coating hard materials of different nature, size and morphology can be combined (**Figure 10**). Semi-finished products can be further processed by plasma arc-, laser beam- or water jet cutting and assembled to more complex structures by screwing or welding. In contrast to components made of cemented carbide SWP can be shaped afterwards by warm forming up to a certain bending radius without cracking (**Figure 11**). Depending on the nature and volume fraction of the hard particles the wear resistance can be tuned according to the specific application needs. “Eco” is the most economic grade with improved wear resistance and surface quality compared to surface welded coatings. The top grade “Premium” is almost close to cemented carbide in terms of wear resistance but with

less brittleness and susceptibility to cracking. **Figure 12** shows the sliding wear properties in comparison. Values for the weight loss were determined by a friction-disc test without vibration and impact shock.

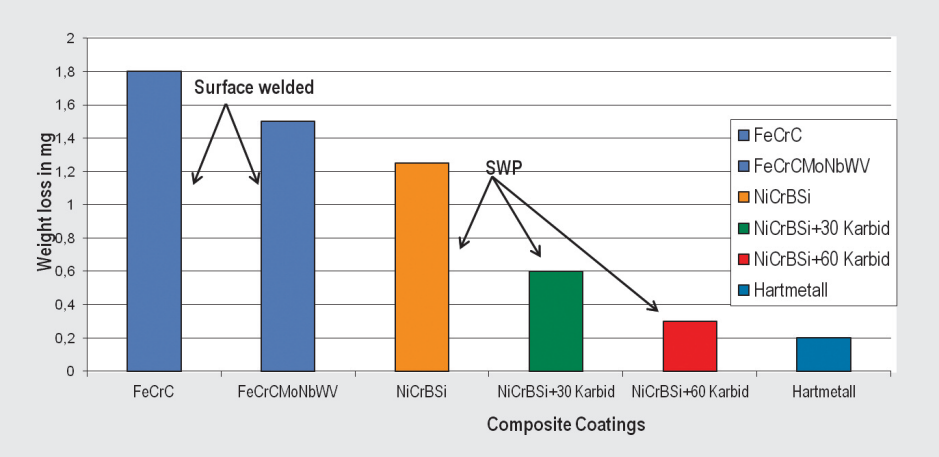

Figure 12: Wear resistance of SWP in comparison

All SWP composite coatings are suitable for high-temperature application and exhibit a corrosion resistance comparable to nickel based alloys. Actually SWP successfully replaces cemented carbide within components used for plastic granulate manufacturing equipment, where predictable long term reliability counts more than maximum hardness. Other typical application areas for SWP are wear resistant plates, slides, transverse baffles, mixing and grinding components and separators.

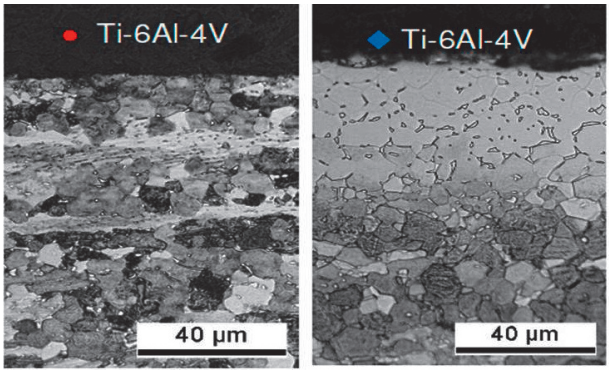

Figure 13: Microstructure of Titanium Grade 5 before (left) and after (right) ODH treatment

5 Wear protection of titanium by heat treatment

Titanium and its alloys are promising materials for lightweight structures, possessing a favourable strength to specific weight ratio. One major disadvantage is low hardness and as a consequence poor wear resistance. Applying thin wear resistant coatings onto the component surface is ineffective due to low stiffness and the so-called "eggshell" effect. With ODH (**O**xygen **D**iffusion **H**ardening) it is possible to improve surface hardness of titanium and some of its alloys by heat treating in a special furnace atmosphere. Oxygen atoms are introduced into the border area which then diffuse into the bulk material, resulting in a lattice strain and significant hardness increase. There is no oxidation of the bulk material. **Figure 13** shows the structure of untreated (left) and ODH-treated titanium grade 5 (right) [5].

The impact of ODH is already visible in the microstructure and a hardness measurement reveals a surface

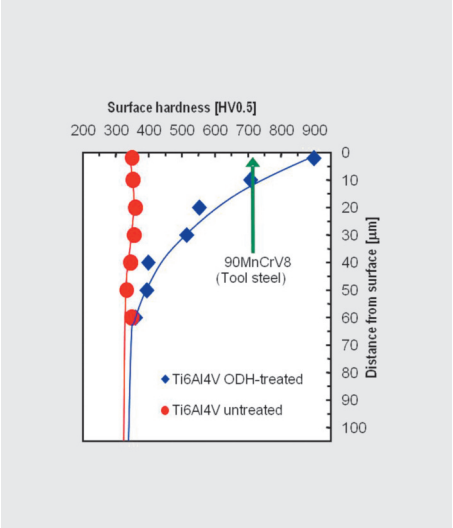

Figure 14: Hardness profile of Titanium Grade 5 before (red) and after (blue) ODH treatment

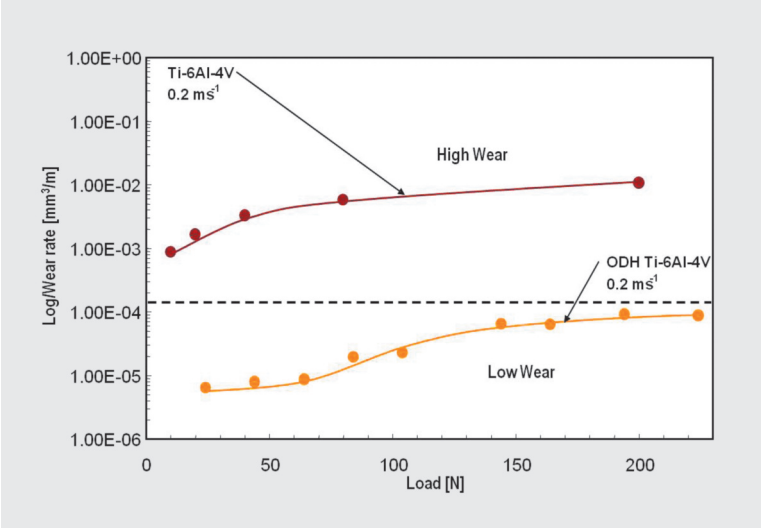

Figure 15: Results of pin-on-disc tests for Titanium Grade 5 against steel 90MnCrV8 without (brown) and with (yellow) ODH treatment

hardness of almost 1.000 HV0.5 which is almost 3 times the hardness of the bulk material. Typical for diffusion based processes the hardness drops down to the bulk material level across a penetration depth of approx. 0.06 mm (**Figure 14**). The positive impact of increased hardness on wear resistance is proved by a pin-on-disc test. With respect to the mentioned test conditions the wear rate of titanium grade 5 could be reduced by magnitudes (**Figure 15**).

6 Conclusion

Brazing and sintering processes are an interesting addition and alternative to well-established thin-film techniques, surface welding and thermal spraying to create wear resistant coatings.

Performed in vacuum furnaces a broad range of wear protective alloys and base materials can be processed without oxidation and ensuring a uniform heating, resulting in low component distortion. Both effects can reduce rework and related costs significantly. State-of-the-art equipment ensures high reproducibility and traceable documentation.

Depending on the technique applied coating thicknesses from few tenth of a millimetre up to few centimetres are feasible. This gives the opportunity to locally unify specific materials properties. In some cases the coating process can be performed simultaneously with the hardening of steel parts. With ODH a process is available enabling a significant surface hardness increase of titanium and its alloys with improved resistance against planar abrasive attack.

7 References

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