Original Article: Comparison of Steel Bonded Carbides that are Heat Treatable with Cobalt Bonded Tungsten Carbide

Martin Viberman

Department of Research and Development, UOP, England

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ABSTRACT

In the general field of cemented carbides, cobalt-bonded tungsten carbide groups are the category that has undergone the most development over the past three decades. Arrangements, physical properties, manufacturing methods and application of this class of materials have been reviewed in the cemented carbides article in this issue. In many applications, tungsten carbide bonded to cobalt has certain disadvantages. The properties of titanium carbide bonded to steel can be compared to the same material for tungsten carbide bonded to cobalt as follows:

- ✓ Titanium carbides bonded to steel respond to heat treatment and when the joint is in an annealed condition, it can be machined with conventional machines.
- ✓ Carbide bonded to fully hardened steel can be heated to a variety of temperatures. Hence, it obtains more ductility than tungsten carbide bonded to cobalt.
- ✓ Cemented tungsten carbides are materials with high modulus. Carbides bonded to steel have a modulus that is not greater than that of steel.
- ✓ The coefficient of thermal expansion of steel-bonded carbides is closer to that of steel than to cemented tungsten carbides.
- ✓ Both tungsten carbide and carbide products can be soldered.

Introduction

The wear resistance of carbides attached to steel is much greater than that of wear-resistant machinable steels. In applications where hollow steel tools and steel forming tools are replaced with steel bonded carbide tools, 10-20 times better performance has been observed [1-3]. When compared to wear-resistant cast cobalt materials, steel-bonded carbides have advantages such as machinability and hardenability as well as wear resistance [4-6].

***Corresponding Author: Martin Viberman** (*Viberman.uop.2016@gmail.com*)

Carbide cermet's with different arrangements of steel connection

The wettability and dissolution properties of carbide make this material compatible with a large number of steel alloys for the manufacture of steel bonded carbide cermet's (sbc) [7-9]. Among the many possible arrangements, few of the most important ones have been developed to make real cermet [10-12]. Grade C is an all-purpose cermet with low chromium, low molybdenum alloy steel, and 45% TiC by volume. This cermet is relatively malleable and ready for machining under annealed conditions, and its surface hardness is 70 HRC. This cermet is suitable for applications and abrasive tools and application temperatures that do not exceed 190 degrees Celsius. More than this temperature, the joining of steel alloy is seen to be heated, which results in the loss of hardness and wear resistance [13-15]. CM grade has high chromium, low molybdenum steel bonding arrangement and 45% TiC by volume. Compared to grade C, this cermet is more heat resistant and slightly less malleable [16-18].

Good machinability and readiness to harden at a temperature of 1080 degrees Celsius are other features of this category. This cermet can withstand a maximum working temperature of 525 degrees Celsius. Another category is SBC, which has a lower TiC content, which increases its ductility and thermal shock resistance. Some grades with aging properties provide performance at higher temperatures and greater resistance to oxidation and corrosion [19-21].

Making semi-bonded titanium carbide cermet's to steel

Two main processes are used to produce standard cermet's or specially annealed steel bond cermet's. The first process includes these steps:

- ✓ Preparation of powder mixtures of titanium carbide, iron, carbon and alloys of metal elements in the form of powder in the necessary proportions in a ball mill to obtain the connection of special alloy steel [22].
- ✓ cold static or hydrostatic (all-round) pressure.
- ✓ High sintering in the presence of liquid phase under vacuum.
- ✓ Hot densification and annealing [23-25].

The second process, which is especially used for large parts or special shapes, includes these steps

- ✓ cold static or hydrostatic pressure.
- ✓ Encapsulation in a steel can.
- ✓ Hot isostatic pressing and annealing.
- ✓ Take out of the can [26].
- ✓ This process produces a product that is completely free of porosity, cracks or other internal defects. The latter process is also used for cermet parts attached to a steel base or additional steel [27].

Hardening of cermet's with steel connection

The hardening of cermet's with steel adhesives is done by various processes, which are usually selected according to the availability of equipment at the construction site. Oxidation and decarbonization should be avoided. There are few fractures, twists and deformations [28-30]. Because only half of the mass changes to the martensite state and titanium carbide is permanently hard and does not participate in this process end wear after hardening can often be avoided. Because the size change is small.

Machining and wear

By purchasing unworked, annealed blanks that are standard and suitable, a machine shop can produce advanced tools or wear-resistant parts without using conventional machining methods such as electric discharge machining to do in the annealed condition [31-33], TiC cermet's bonded to steel such as those listed can be machined by normal methods. Most machining operations work better dry than lubricated. Valves, even when new, should be degreased before use [34].

The wear of cermet in its annealed condition leads to its final smooth surface with fast grating operations. For very precise parts or tooling components, final wear is usually performed with aluminum oxide wheels operating at high cermet rates and without coolant. Heavy abrasive tools give good results. To produce complex shapes in mold parts with the forming part, wear forming with special wheels for this work are done in annealed conditions and if needed re-wearing with a low-cost process and after hardening [35].

Titanium carbonitride cermet's

Titanium carbonitride cermet's, widely used as cutting tools, evolved as a result of the development of titanium carbide cutting tools in the 1950s. The primary cermet cutting tool materials contained 70% TiC, 12% Ni and 18% Mo_2C. This sintered material has a density of 6.08 g/cm, its wall hardness is 92 on the HRA scale, and its cross-sectional breaking strength is 860 MPa. Because these materials have high hardness, good resistance and low thermal conductivity, they are suitable for machining applications with light and high-speed cutting. In advanced countries following these issues, complex cermet cutting tools were made based on titanium carbide and nickel molybdenum cermet material [36].

Titanium carbide cermet's with nickel-molybdenum joints were introduced as materials for high-speed tools, but they were insufficient in areas such as formability and thermal shock resistance. This problem prompted research to improve the cutting operation by two prongs, hardening the bond phase and improving the carbide phase. Aluminum seemed to be the best joining metal alloy element for this structure. Using maximum 0.075 mm deformation as a measure of tool wear by adding about 7% of aluminum, the optimal cutting speed will reach the field size. It seems that the maximum strength of the alloy reaches its maximum at about 7%. After achieving the optimal resistance of the field using experimental approaches in the problem, researchers tried to reach a way to strengthen the carbide phase from the same approach. The resistance to deformation in the tool shows a clear change with the addition of vanadium carbide (VC) to the solid solution with the Tic hard phase [37].

At a level of 5% VC, the rate for equivalent deformation is greater than that of a material without this additive. Adding more VC has the opposite effect. However, a further improvement in deformation resistance is obtained by adding more TiN, which is probably due to the effect of solid solution hardening and uniform grain size in the material [38]. The addition of titanium nitride to an alloy cermet containing aluminum and vanadium carbide provides a greater improvement in resistance to deformation than when each composite component is added individually. As resistance to deformation increases, TiN modifies cutting alloys to exhibit greater resistance to thermal fracture, which is an important factor for applications involving fracture cutting such as those in milling operations. occurs, is It is interesting to note that in the final analysis, the improvements resulting from the addition of strengthening elements to the aluminum TiC-N-Mo arrangement were no longer needed.

In compounds including TiC-VC-TiN-Ni-MO, by adjusting the amount of each component, the properties required for specific machining operations are optimized with these complex cermet's, harder workpieces can be machined at higher cutting cermet's, even in intermittent cutting applications such as grinding to some extent. titanium carbonitride cermet's were used. These materials were registered in 1976.

According to the abstract of the registered text, carbonitride alloys are based on a system of selective arrangements with a return range, in which titanium and M metals of group VI are present as base metals. The connection is selected from iron group metals as well as transition refractory metals of group VI and includes 5 to 45% of the weight in the structure [39].

Attributes

The microstructure of the titanium carbonitride sample at 1500x magnification shows individual angular carbides of larger size surrounding carbides, which are more or less freely distributed throughout the field [40-42]. Each larger carbide is separated from the next carbide of similar size by a distance of about one to three times its size. After that is the transitional phase which is responsible for the resistance of sermet.

A conductive compound has a hardness of 93 on the HRA scale, a density of 6.02 grams per cubic centimeter, and a tensile strength of about 1550 MPa.

A similar and slightly more malleable compound produced by Teledyne-Firth-Sterling has a hardness of 8.91 on the HRA scale, a density of 6.3 grams per cubic centimeter, and a cross-sectional tensile strength of 2070 MPa. Based on general experience with cemented carbides, it is expected that the fracture toughness of the titanium carbonitride cermet section will differ from that of the metal bonding section in the overall composition [43].

The hardness of these materials at high temperatures as well as at room temperature is comparable to conventional cemented carbides. Of course, the strength and ductility of the titanium carbonitride compound is lower than normal cemented carbides, which limits the cutting feed rate in coarse and heavy applications. On the other hand, when converting to 4340 steels in various cermet's. The wear resistance of the cutting edge depends on the cutting temperature. Pressure welding is the result of edge heating at low temperatures. While the leakage and oxidation processes occur due to high cutting temperatures, and the enthalpy of free state formation of titanium carbonitride, which is high, increases the resistance to the formation of accumulated edge, pit formation, and crust formation [44].

A favorable side wear rate when cutting a malleable steel at a relatively high cutting speed is a property of this cermet that enables it to extend tool life and increase stock removal with form-changing tools.

Applications

Cutting tools made of titanium carbonitride cermet are used for high-speed milling, forming and semi-finishing of carbon steel and stainless steel. The resistance to pitting and lateral wear that results from this material tends to preserve the cutting edges [45].

As a result, excellent finish surfaces and tight tolerances are achieved with more work on the product and even superalloys and other materials that are difficult to machine. More details on titanium carbonitride tool materials are given in the article "cermet's in machining" in Issue 16 of the 9th edition metals handbook.

Tungsten carbide cermet's bonded to steel

In an effort to improve the ductility of TiC cermet's attached to steel in the research of Chinese metallurgical researchers, their attention was drawn to tungsten carbide as a hard phase as a result of the tungsten carbide cermet tool attached to steel in the group of machinable and hard enable materials. to be the greater ductility of WC-based cermet is a property of the small moisture angle with steel under high temperature, even when sintered in normal hydrogen, as well as the density of the piece and the fact that the solubility of WC in iron group elements is much higher than the solubility of TiC particles in the steel structure. The value of compressive strength equal to 7.35 J/cm^2 is high not only because of cemented carbides with steel glue, but also any cemented carbide material is involved in this. This cermet is used for heavy pressure applications such as cold riveting or extrusion, heavy pressing, cold forming, cold forging and ball heading. For example, in ball head tools [46], the performance of cermet's attached to WC steel is 10 to 100 times better than rivet molds that were used before.

Chrome carbide cermet's

Cermet's, which contain chromium carbide as the main component, have unique properties that have made them useful for certain applications in tools and chemical industries. This class of material is basically a cemented chromium carbide of the term Cr_3C_2 bonded with nickel or an alloy of nickel and tungsten. Cr_3C_2 powder is produced by the reaction of Cr_3C_2 with carbon at a temperature of about 1600. Melting aids of lower chromium carbides are added to control carbon balance and keep free carbon low. Carbide making operation is used to produce these cermet's. Some of the interesting features and specific applications of these Cr_3C_2 cermet's are as follows:

- ✓ A relatively high coefficient of thermal expansion that allows direct soldering to steel, if boron-containing lubricants are used [47].
- ✓ Glossy and durable surfaces that have high reflectivity and the ability to pay for smoothness and flatness in appearance, combined with thermal expansion properties make the material suitable for rectangular cube gauges, micrometer tips and other measuring tools.
- ✓ The non-magnetic nature makes measuring easy despite the nickel adhesive [48].
- ✓ Excellent coating and resistance to corrosion and rusting, for example against saltwater ingress at high temperatures up to 85°C, which makes cermet suitable as a bearing and sealant or wire rings.
- ✓ Wear resistance that is much higher than any normal alloy resistant to rust and corrosion [49].
- ✓ Erosion resistance at high temperature up to at least 1000 degrees Celsius.

Applications and features

Applications of chromium carbide cermet's include high temperature bearings and sealants. Components of valves, sprinklers or trumpets and guides or conductors that operate at elevated temperatures and a number of measuring and measuring instrument components. Although finding moderate use in a number of the above-mentioned applications, chromium carbide has recently been neglected and is no longer recommended as a standard grade by the cemented carbide industry. However, it should be noted that chromium carbide has potential in a new field of cermet's application in the coating area. For example, an advanced coating for gas bearing journals mixes chromium carbide for coating and nickel alloy for bonding, silver for lubrication up to 500 to 900. Cermet coatings are plasma that are sprayed from powder mixtures and processed by crushed diamond. A typical composition of such a mixture consists of an alloy of 32% Ni, 10% Ag and 10% BaF_2CaF_2 eutectic with a balance of Cr_3C_2.

Other carbide-based cermet's

Other refractory metal carbides such as zirconium carbide (ZrC), harmonium carbide (HFC), tantalum carbide (TaC) and niobium carbide (NbC) have been experimentally produced and investigated for high temperature applications. They have the highest melting points in the bath of known compounds. Harmonium carbide melts at 3890°C, Nan thallium carbide melts at 3800°C, Zirconium carbide melts at 3530°C, and Niobium carbide melts at 3500°C. All these carbides have poor oxidation resistance at high temperatures and become extremely brittle and brittle. Cementing these carbides with flexible bonding metals does not improve these characteristics enough to make the resulting cermet's competitive with industrial carbides ready for tool and structural applications at high temperatures. The use of small amounts of niobium and tantalum carbides as melting aids to titanium carbides to produce cermet's with resistance to oxidation at high temperatures was mentioned before. Uranium carbide cermet's are used significantly in nuclear reactor technology. Because carbon has a cross section of neutrons. Uranium carbide is suitable as a fuel element for neutron trading. This compound has the thermal conductivity of uranium dioxide. In addition, it has a melting point of 2300°C or 4170°C and creep resistance up to 1000°C (1830°C). The main disadvantages of uranium include its brittleness and fragility, poor resistance to thermal shock and destruction in aqueous environments at high temperatures. Adhesive matrix metals selected for the cross section with low thermal absorption, such as beryllium, zirconium, niobium and molybdenum or iron, do not reduce the disadvantages of the UC ceramic phase. Therefore, these types of cermet's are known as industrial applications behind experimental reactor technology in the United States of America and countries outside of it. Silicon carbides and boron pseudo metals, SiC, B_4C, have considerable industrial importance and have various uses such as very hard tools and electric rheostat heating elements.

These compositions are often used without metal bonding phases, leading to a product that falls outside the material classification of cermet's, but an exception to this is cermet's in which the quasi-metal carbide with a single phase The metal background that forms the main contribution are combined. Some of them are very important in nuclear reactor and aerospace technology. Some others have recently been used in the manufacture of automatic motors and airborne electronics.

Aluminum-boron carbide cermet's

Natural boron has 18%. 8 is from a B-10 isotope, which itself has a high neutron cross-section, that is, it has a high capacity to absorb neutrons. Therefore, boron and alloys containing boron or intermetallic compounds are very useful for controlling a nuclear reactor.

This feature has caused Boron Carbide (B_4C) to be considered as a desirable and suitable neutron absorber due to its economic existence in powder form, as well as its high purity and permanent quality.

Low density and high chemical stability are desirable characteristics of this powder. Boron carbide is used in most aluminum cermet's used for neutron absorption elements in nuclear reactors. In some cases, europium, dysprosium and samarium oxides are also considered desirable. Cermet compounds in AL-B_4C composition have various applications in certain parts of the nuclear industry. Especially for water-cooled reactors that operate in the appropriate and useful temperature range of aluminum. Some common components are flat plates with dimensions of 2.5 x 20 x 1370 mm. Other components with more complex shapes include reactor control wires with an outer diameter of 43 mm and a wall thickness of 0.5 mm. Special processes of powder metallurgy are required to produce components of this type in accordance with strict dimensional tolerance and durability and a high degree of continuous critical chemical resistance. Successful processes for making Al-B_4C cermet's include the following steps:

- ✓ By mixing the active powders.

- ✓ Cold compaction of powders in the form of ingots.
- ✓ Sintering
- ✓ Integration and hot integration of ingots.
- ✓ Hot extrusion
- ✓ Cold rolling.

Special multi-step mixing techniques are required when producing mixtures with very low concentrations of neutron absorbers. Uniform powder mixtures invariably load the control rods with a very uniform distribution of neutron absorbers along their entire length. The powder metallurgy process ensures higher levels of consistent compositional accuracy that are proven by chemical analysis. To avoid undesirable contamination, thorough cleaning is required when mixing equipment is transferred from one compound to another. Hot densification of the ingot before extrusion is a necessary and essential step. This step may include an expensive back-up step. When the hard phase in a cermet exceeds 15 to 20%, the composition is no longer elastic and hot working or extrusion becomes more difficult. Concentration compression directly in Al-B_4C mixtures at room temperature does not yield acceptable results, but it should be noted that other groups have been successful in producing nuclear control rods by the powder rolling technique. For example, Brome's carbide is obtained through a direct and continuous powder rolling process. These compounds contain 20% wt (about 50% by volume) of boron carbide. The strip is pre-compressed, sintered and brought back to full density by a sequence of glazing and rolling operations. The construction stage and microstructural features of Al-B_4C cermet's and their assembly into different structural elements have been explained and drawn by Halverson and his colleagues.

Bored head

Because metal borides are generally more refractory than titanium carbide, boride-based cermet's are especially important for applications that require a material with corrosion resistance and heat resistance. Such as materials that are in contact with hot reactive gases or molten metals. The transition metal diborides of hafnium, tantalum, zirconium and titanium have very high melting points, which fall from 3250$^{\circ C}$ to 2800$^{\circ C}$, respectively. Molybdenum boride (MoB) and chromium boride (CrB) melt at much lower temperatures. The oxidation resistance of transition metal borides above 1100$^{\circ C}$ (2000$^{\circ F}$) is better than that of TiC and roughly follows the order of decreasing melting point. Oxidation resistance and strength characteristics at high temperatures can be increased by reacting the crystals with small amounts of other thermally stable compounds such as SiC or molybdenum disilicide ($MoSio_2$) before the powder treatment process into solid bodies. Because these metal borides have relatively high thermal conductivity and high thermal stability, they are not dependent on a supporting metal bonding matrix for thermal shock resistance and strength like nickel-chromium alloys in TiC cermet's. Boride phases alone in their refined state are highly hard, polished and abrasive, but their hardened bodies present difficulties in assembling them into efficient and useful products as well as in their related services, especially in environments containing dynamic gas or fluid flow creates metal. This defect can be reduced in some cases with a metal bonding phase. Due to some thermodynamic reasons, this adhesive phase is limited to 2 to 5% of the atmosphere to a maximum of 10% at. The main and suitable metals for cementing boride grains are iron, nickel, cobalt, chromium, molybdenum, tungsten and boron or some alloys of these metals. Eutectics that have a low melting point in boron-iron and boron-cobalt systems, and especially boron-nickel, limit the amount of related bonding metals to a small extent. The effectiveness of iron and cobalt, especially as titanium diboride (TiB_2) and zirconium diboride (ZrB_2) binders, is later reduced by the formation of very brittle and brittle intermetallic compounds, while chromium and boron alone or in combination with Each other produces eutectics with high melting point with these borides. Melting aids up to 5wt% and 10wt% Mo or W can be successfully used as a binder without forming low melting point phases. Intermediate metal borides are produced as pure crystals through such processes as solid-state reaction of boron metal and reaction of metal or its oxide with boron carbide, reduction of metal borooxides with carbon or reactive metals, or molten salt electrolysis. Mixtures of these borides and adhesive metal powder act as cermet products, which are processed through powder or ceramic metallurgy techniques such as hydrostatic process or slurry casting followed by vacuum sintering, or through isostatic or non-axial working pressure. are done the high costs of producing borides and working with fragile products with the necessary precision have limited the applications of these cases in which the unusual characteristics of these materials are necessary and necessary. In addition to high costs, these materials have completely poor mechanical properties. Therefore, very few boride-based cermet's are able to continue for practical applications in industry.

Conclusion

Zirconium boride cermet's

Comprehensive studies of the characteristics of this intermediate boride have been conducted about 25 years ago. Its good mechanical properties at high temperature and its very high melting point, as well as its significant decrease in brittleness and brittleness with increasing temperature, have made it one of the rare borides that have attracted the attention of researchers. Addition of about 2 to 5 wt% binder B to ZrB_2 makes the material suitable for very high temperature applications including high performance propellants, rockets, and jet propulsion systems. Oxidation resistance in zirconium boride can then be increased by 15% by reacting it with SiC, and the condensed cermet bodies successfully resist oxidizing environments. These materials have been the target of comprehensive investigations for their use as spray valves for the entry of propellant liquids in rockets. Probably the most important feature of zirconium boride is its resistance to rust and corrosion at high temperatures, as well as its non-wetting feature when in contact with molten aluminum, brass, and molten zinc and lead. As a result of the use of this cermet in systems, work with molten metals has begun. Practical examples of this include pump impellers and bearings in die-cast alloys or liquid iron, nozzles or spray horns for disintegrating metal powders, and furnace parts that come into contact with reactive metals or vapors and gases.

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