Original Article: Seepage (pulling of liquid metal into the pores of another metal by capillary forces)

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ABSTRACT

Percolation is a process similar to sintering with a liquid phase, except that here the solid phase is first formed in a porous molded body, and the solid metal phase is formed from the outside during sintering and is allowed to permeate the porous system. Additional shrinkage can be prevented by liquid phase sintering, which results in dimensional stability of the product except for one percent growth, which is due to a thin surface layer of liquid metal formed on the part. This method is used for systems that have two or more components and their melting temperatures are very different. Excluding the hot compaction method, percolation is the only powder processing method that can produce a perfect density close to the lattice shape. All other densification processes require the material to shrink and thus destroy the correct shape and dimensions. With machining, pressure densification or powder injection into the mold, seletonization is formed earlier than percolation, complexity in the design of parts such as cuts, internal angles and multiple surfaces that can be released to size in high density parts. which are produced by extrusion or hot pressing are not possible. Another unique feature of percolation is that under suitable conditions for segment angles and limited solubility between low-melt and high-melt phase systems, fully entangled continuous networks can be obtained. This is an important issue for manufacturing products that must have a combination of high thermal and electrical conductivity with an acceptable level of strength and resistance to erosion. The process used for TiC cermet's consists of 2 steps. First, approximately 60% of the density of the carbide skeleton body is formed at close to (5000psi), the ingot is vacuum sintered at a temperature of about 1300degrees Celsius (2370degrees' final phase) and then the external shape is machined. (For example, a turbine blade). The second step involves placing the skeleton form in a closed mold that has a metal-filled hopper at the top that feeds the skeleton by gravity and liquid to its required levels.

Introduction

The The mold is made of graphite and its housing is covered with refractory ceramic powder to act as a mediator with the TiC skeleton [1-3]. The ceramic coating is chosen because it does not react with the titanium carbide up to high seepage temperatures and because the powder shrinks at a controlled rate that allows the gaps to form uniformly in all directions [4-6]. The closed mold is heated up to 1400 to 1500 degrees Celsius

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(2250 to 2730degrees of the final phase) in a vacuum furnace; This heat is higher than the melting temperature of permeation alloys such as 70Co-24Cr-6Mo, 80 Ni-20 Cr [7-9]. During the percolation process, the liquid metal first fills the gap between the coating and the outer surface of the skeleton with capillary forces and then penetrates into the pores of the TiC section. After the furnace cools, the fully permeated product can be easily removed by breaking the ceramic coating without damaging the graphic mold and the mold can be reused [10-12].

Graded cermet parts can be made with different TiC skeleton densities using a special filled mold and adequate pressing. For example, a turbine blade can be made in such a way that it has a high distribution of titanium carbide and therefore has a high resistance at the center of the blade and at the transfer point at its root [13-15]. Also, the turbine blade should have a cover with an almost metallic composition in two sheets, especially on the edges of the blade, which are mechanically sensitive to impact. Also, at the root where teeth are needed to connect the blade to the turbine wheel. The percolation process has been successfully applied to other cermet systems; It has been particularly successful when used with intermediate reactions. An example of such an application is the production of complex ceramics that are reinforced with grains of another composition and bonded with a third type. The preformed ceramic is a quasi-metal carbide, the adhesive is an active metal with a relatively high melting temperature, and the grains are the reaction products of the carbide and the adhesive.

The unique composition of the microstructure of such a ceramic, which is secured by a small plate, is achieved by gravity seepage of molten metal into preformed pores or carbide packing. In the case of B_4C ceramic and the percolation of zirconium metal into it, the controlled oxidation of the contact surfaces creates a new phase, ZrB_2, which is abundantly deposited in the form of grains and makes the ceramic stronger.

A similar result is obtained with fillers or preformed SiC particles that are fused with aluminum metal and permeated under oxidizing conditions; The reaction product in this case is AL_2O_3. the container or mold used in the process is coordinated; The process is carried out in an atmosphere of argon. The temperature of the reaction and seepage depends on the melting point and liquidity of the metal. This temperature can be up to 2000 degrees Celsius (3630degrees of the final phase) in a system that includes zirconium.

The time to complete the percolation and reaction is 1 to 2 hours, and the final product has 5 to 15 percent metal glue left. The ZrB_2 / ZrCx / Zr-type micro-surface-cemented infused ceramic system offers a good combination of high strength, high fracture toughness, and high thermal conductivity. This combination is an interesting option for materials used in rocket engines and cover parts. The rest of the systems that have been successfully produced by the percolation method or can be used with this method are combinations of TiB_2 and nickel ceramics, TiC with steel, WC with cobalt, ALN with aluminum and AL_2O_3 with aluminum as the second phase have their own Boron carbide leaching process and active metal-boride cermet’s have been successfully used to make high strength, hard and light weight products that can provide a good combination of hardness with high thermal and electrical conductivity [16-18].

The process involves permeation of molten active metals, especially aluminum, into chemically prepared boron carbide, or it can use metal-boride as starting components such as powders or low-proportion filaments, which they accumulate in the spongy part of the ceramic porosity. This process is a way to seep molten aluminum into the thermally prepared sponge space. Conventional chemistry or particulate chemistry is used to control the chemical reaction of castings and leaching processes. It is also possible to integrate sponge parts by injection molding in single-step processes. The key to the process in the chemical control of the surface is the initial constituents of the reaction. In a two-step process, the first step is to produce precise geometric features that can also be molded using pre-prepared adhesives. In the second step, the connection escapes from the produced body and leaves a skeleton ready for oozing.

Connection and microstructure

Various physical and chemical aspects of bonding between dissimilar phases and the size of ceramic grains placed in the metal background are very important for the properties and characteristics of cermet's. Reference 28 includes the basic topics of the connection mechanism, especially in the Metal-TiC system [19].

Connection: In general, due to the fundamental difference in the nature of ceramic and cermet metal components, none of the solid state connections are used. Instead, compounds are formed as ionic bonds, covalent bonds, and metallic bonds. The first type that is widely used in cermet is oxide-based ceramics, which have little strength and simple adhesion to hold to the metal phase. The second type of connection that is widely used for systems containing silicon and carbon is graphite, diamond and SiC. The resistance of this connection is also limited. Cermet forms a strong mechanical bond when the metal bond is combined with a covalent bond. Metal-carbide and metal-boride systems are examples of types of cermet's in which this combination occurs [20].

Solubility: The high adhesion strength between metal and ceramic is much higher in cemented carbides and boride with partial or partial dissolution [21].

During the sintering process, surface-active carbide or boride particles are dissolved in the liquid phase, and carbon, boron, and transition metal atoms are dissolved in the solid particles during cooling. Depending on the system, these elements remain undissolved in the binding phase with low levels of up to several percent. Even in other cermet types, this partial dissolution mechanism is an advantage. Because they produce a level of alkali metal. Metals known as junctions are more readily oxidized than semimetals such as borides and silicide's. For example, in the Cr-Al_2O_3 system, a surface layer of chromium oxide (Cr_2O_3) on the chromium particles forms a solid solution during the sintering process with closed control and an atmosphere that slowly carries out the oxidation process during which AL_2O_3 is formed. The result is very high adhesion. Similar to metal-alkali transition metal oxide bonding, increased adhesion can be achieved with an intermediate layer of copper oxide (CuO) in the Cu-AL_2O_3 system or with a layer of titanium nitride (TiN) in the nickel-magnesium oxide (Ni) system. -MgO) [22].

Moisture: Another important aspect in the bonding mechanism is the ability to wet the solid phase with the liquid metal component. This capability is controlled by the surface energies of the system during liquid phase sintering. The relationship between surface force vectors is given by this equation:

$$\sigma sv - \sigma sl = \sigma lv \cos ə$$

In this formula, σsv, σsl and σlv are surface energies of vapor-solid interface, solid-liquid interface and vapor-liquid interface respectively. The contact angle is a parameter that can be accurately measured. In oxide metal-ceramic systems, the surface energy of the vapor-liquid interface in the metal is greater than the surface energy of the vapor-solid interface in the oxide, and the viewing angle remains greater than 90 degrees [23]. Consequently, during liquid phase sintering or percolation in neutral atmosphere, the liquid metal will not remain in the solid pores, but tends to sweat. If the contact angle is smaller than 90 degrees, the liquid metal phase remains in the ceramic pore system, and when the contact angle reaches 0 (zero), the connection becomes stronger. This is the case with cobalt bonded cemented carbides.

Microstructure

The nature of bonding in cermet's is strongly related to its microstructure. This is especially important for carbide cermet's. Because in these materials, the properties are strongly affected by variables such as the shape, size and dispersion of carbide grains, the amount of carbide grains in the metal field, the position and structure of the field, and of course the degree of adhesion of two phases. Although these variables are continuous with each other.

They can be selected for specific effects. A very fine carbide grain tends to increase strength and hardness, but a coarser grain size up to about 2.2µm can increase the hardness of cemented carbides [24-26]. The sharp corners that are common in WC grains cause the strength of cemented carbide to decrease only slightly; In cermet's with higher metal content, these grains increase local stresses in the brittle metal field [27].

The good dispersion of carbide grains in the metal field causes the grains to separate from each other, which limits the tendency to create a fracture that starts from one grain and spreads to the others that are in contact with the first grain [28]. The same reason for any second hard phase that may be formed during sintering and bridging of the original grains [29].

Conclusion

Chromium carbide and nickel aluminide (Ni_3AL) are examples of field reaction products that can form carbide grains in TiC cermet's. Generally, depending on the amount of carbide, the resistance and hardness increase and the coefficient of thermal expansion decreases. If the microstructure field is in the form of a continuous phase and has enough volume to avoid the state of triaxial stresses, the ductility is also improved. Context is important in several ways. High ductility and durability are necessary to reduce the stress caused by the hard phase and create low safety to prevent catastrophic fracture during work. The choice of alloy must be based on the context, as the context is an available source of reactive products that can fuse with the carbon grains to form a continuous hard phase. The location of the metal substrate also affects properties such as corrosion and oxidation resistance, machinability and weld ability. A good bond between the carbide and the metal phase is essential because the bond must transfer stresses from one phase to the other. Therefore, any distance between the surface of the carbide particle and the ground is harmful. The importance of these adhesives is emphasized by an example of good bonding in Ni-TiC with addition of molybdenum. The contact angle of liquid nickel in the composition of TiC in hydrogen is 17degrees, but this angle is almost zero with the addition of molybdenum. Cermet's of this type contain molybdenum and nickel as a solid solution in the adhesive alloy. (Ti, MO) C_1-x. During the sintering process, molybdenum reacts with the TiC particles to form a case of (Ti, MO) C_1-x that surrounds the core of each TiC particle. This mechanism tends to increase the wettability of the carbide phase with bonding. The result of this is an increase in resistance, but the basis of fragility, especially the susceptibility to chipping and cracking, does not decrease.

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