Eurasian journal of Chemical, Medicinal and Petroleum Research

2023, Volume 2, Issue 4

Original Article: Examining Cermet's (a Homogeneous Mixture of Metals or Alloys or One or More Ceramic PhaZes)

Frank Ablin Derosow

Department of Chemical Engineering, Calgary University, Canada

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Citation F Ablin Derosow, **Examining Cermet's (a Homogeneous Mixture of Metals or Alloys or One or More Ceramic Phases),** *EJCMPR* . 2023; 2(4):175-186.

https://doi.org/10.5281/zenodo.8282400

Article info:
Received: 10 May 2023
Accepted: 25 August 2023
Available Online:
ID: EJCMPR-2308-1094
Checked for Plagiarism: Yes
Peer Reviewers Approved by:
Dr. Frank Rebout
Editor who Approved Publication:
Dr. Frank Rebout

Keywords:
Homogeneous Composition, Metal, Alloy, Ceramic Phase, Cermet.

ABSTRACT

Cermet, an abbreviation used worldwide for a homogeneous mixture consisting of metals or alloys or one or more ceramic phases comprising approximately 15 to 18% by volume and relatively little solubility between the metal and ceramic phases at the preparation temperature. It is being used. A good definition of the word ceramic can be found in "Ceramic index". Any unusual, non-metallic product that is exposed to high temperatures during manufacture or use. By way of example, but not exclusively, the ceramic is a metal oxide, braide, carbide, or combination or mixture of such materials; In which there are anions that play an important role in atomic structure and properties. With a specific source on cermet's, this definition of a ceramic component can be expanded to include nitrides, carbonatites, and silicides. In a broad view, cermet's are like a special type of hard and refractory materials in the general class of metal composites. This topic is well covered in scientific papers, especially in the spectrum of specific comparable fracture volumes and metallic components. Compared to composite layers, the combination of metal and non-metal in cermet's occurs on a very small scale. The non-metallic phase is usually non-filamentous, but a number of fine non-coaxial grains are formed, which are well dispersed and attached to the metal matrix. If the metal or ceramic component is often in the form of filaments, the material should be considered as a composite material. The connection between the non-metallic phase and the metallic background creates important effects among cermet's; This greatly affects the phase associations, solubility and wetting characteristics associated with ceramic and metal components.

Introduction

Cermet's can be classified according to their refractory components. In this system, the main categories of cermet's are characterized by the presence of six components. The difference between the size of the ceramic component is related to the system and its application [1-3]. This can be as fine as 50 to 100 micrometers, as in some types of cermet's based on uranium dioxide (Uo$_2$) used for nuclear reactor fuel elements, or as fine as 1 to 2

***Corresponding Author: Frank Ablin Derosow** (*fa.derosow@gmail.com*)

micrometers as in fine particles of cemented carbides. has been there is If the ceramic component is smaller and smaller in size, the material can be considered as a class of hardened alloy and thus it is out of the accepted definition for cermet's [4-6]. The main goal of combining metal and ceramic on a normal scale is to achieve a desired quality and remove the inappropriate and unwanted properties of both types of materials [7].

An outstanding example of the desirable properties obtained from ceramic and metallic materials is the variety of hard metals that are made from cemented carbides. Cemented carbides have enjoyed a constant growth in the last 6 decades. During this time, the development of cermet/hard metal tool materials went from tungsten metal based carbides to complex carbide and nitride based materials [8-10].

Carbides, carbonitrides, nitrides, oxides, borides and all kinds of carbonaceous materials. The metal adhesive phase can be composed of various elements alone or in combination, such as nickel, cobalt, iron, chromium, molybdenum and tungsten; It can also include other metals such as stainless steel, super alloys, titanium, zirconium or some alloys with low melting point of copper or aluminum [11]. The total volume of the adhesive phase depends entirely on the desired properties and the intended end use of the material. This volume can range from 15 to 85 percent, but for cutting tool applications, it is generally kept to less than half of the total amount (for example, 10 to 15 percent by weight) of metal bonding for each cermet in order to achieve the desired structure and properties are selected for a specific application. The group of ferrous metals and their alloys are dominant in the class of cemented tungsten carbide hard metals; Nickel and, to a lesser extent, cobalt and iron have favorable combinations for high hardness and good hammer ability. However, the adhesive material for a cermet can be selected from a group of reactive metals, such as titanium or zirconium, or it can be selected from a series of refractory metals that include chromium, niobium, molybdenum, and tungsten [12-14]. Less melting metals and alloys, primarily those based on copper and aluminum. They are off the list of adhesives and off the bottom of the thermal scale. However, aluminum is often present in metal-based composites [15].

Cermet's based on carbide

Carbide-based cermet's are the largest group of cermet's, even if the word cermet is used too restrictively considering the wide range of cemented carbides used in tungsten carbide (WC)-based cutting tools and cladding parts. Since the time of cermet technology, the prominent concept has been that these materials are based on TiC as the main hard part and also the refractory part, which, by connecting to each other, form any type of refractory malleable metals or alloys more than that used for cemented tungsten carbides) [16-18]. TiC cermet's are used in tools and resistant coatings, as well as in systems that are used for high temperatures and high pressures. They are also used in corrosive environments [19].

SiC and B_4C-based cermet's, which are generally classified as metal-based composites, have gained special importance in industries, especially in anti-wear and anti-corrosion coatings and parts; These materials have also been used in nuclear reactor applications; Materials based on chromium carbide (Cr_3C_2) have been used for various types of corrosion-resistant applications and also as graduated and indicator blocks; However, they seem to have lost much of their industrial use [20-22].

Carbonitride-based cermet's

Carbonitride-based cermet's can be produced with or without different types of carbides (MO_2C being the most important); They are bonded together with normal cemented carbide adhesives. Currently, these materials are among the first cermet's to be used in tools [23].

Their increased strength, which makes these materials suitable for high-speed cutting tools, is due to improved adhesion between the hard carbide grains and the bonding metal. The improvement of adhesion is a result of mixing and mixing (without changing its properties) in the four systems of TiC, TiN, MOC, MON, which causes a reciprocating displacement in the two phases of the same structure, which basically improves the wettability of the adhesive [24].

Nitride-based cermet's

Nitride-based cermet's form a special class of tooling materials. Titanium nitride, and especially Cubic Boron Nitride (CBN), when combined with a hard bonding agent, produce excellent cutting tools. Titanium nitride and zirconium nitride (ZrN) which have attached themselves to hard metal elements are produced for purposes that are resistant to erosion and also resistant to specific heat [25-27].

Oxide-based cermet's

Oxide-based cermet's form a group that includes UO_2 or thorium dioxide (ThO_2), which are used for nuclear fission components in its fuel elements; Al_2O_3 or other highly refractory oxides are used by builders and those who deal with metals in liquid form (for example, conduits for the flow of molten metal) and other parts of the furnace; and SiO_2, which is suitable for friction elements. A mixture of Al_2O_3 with TiC is suitable for hot machining tools [28-30].

Boride-based cermet's

Boride-based cermet's, their dominant phase is boride, one of the transition phases. This cermet's provide resistance to wear and high temperatures for working with non-ferrous metals such as aluminum in the molten or vapor state. A combination of ZrB_2 and SiC is resistant to erosion caused by rocket propellant chemical gases [31-33].

Cermet's containing carbon

Carbon-containing cermet's are materials that contain graphite in different proportions. These materials are used for paints and electrical connections or as a small component that provides lubrication in wear elements. Also, in this category, there are diamond pieces inside the metal background, which are used for special tools [34-36]. The methods used for powder preparation, shaping, heating or sintering and shaping operations of cermet's are very similar to ceramics and powder metallurgy processes (P/M). The main processes are cold forming (cold forging) and sintering, pressure sintering and percolation (in metallurgy, the drawing of liquid metal into the pores of another metal by cohesion forces is called) [37]. The process of cold working pressure includes compression is made by all-axis uniaxial and uniaxial compression methods. The powder compounds are pressed at a pressure of 35 to 100 megapixels (5 to 14.5 KSI). The main method involves pressing a powder that is lubricated with wax. Of course, by dry method in strong metal molds with two pressing plates facing each other, for long bars or pipes with the same cross-section [38], these molds are made by extrusion method, which put powder particles in glue or suitable organic wax. To make large complex shapes, the dry powder is placed in a flexible mold and compressed from all directions by hydrostatic pressure from a tightly closed reinforced steel cylinder.

Powder preparation

The first step in the cermet production process is mixing and grinding the constituent powders. This mixture consists of the material that forms the hard phase in the form of powder and metal or special metals in appropriate and necessary proportions for the composition of the alloy adhesive, which are ground in a ball mill. Bullets are made of tungsten carbide or, better yet, of a highly sintered cermet [39-41]. The mill can be homogenous with the same type of cermet material to reduce the possibility of mixing with contaminants. In addition to conventional ball mills, high-energy burning ball mills and abrasive mills are also used. With newer types of grinders, things like grinding time, energy and space can be reduced [42]. During the grinding process, the hard phase particles are crushed and completely covered with the adhesive metal. Organic liquids such as hexane are used in this process to reduce the rate of temperature increase and prevent the oxidation of materials. After the powders are ground to 325 mesh or less, the mixture is dried before any further processing and use [43]. Then a lubricant is added and the powder mixtures are prepared to be compressed in the automatic press machine in order to form larger particles (agglomerate) so that they can easily flow through the opening of the feed chamber of the machine [44-46].

Sintering

Not all cermet's require liquid phase sintering, but almost all of them use this process to turn the new part into a solid, strong, and strong product. During the sintering of pressed parts from the powder mixture, depending on parameters such as the exact chemical composition of the powder mixture, the sinter temperature or even the heating rate up to that temperature, the conditions for establishing heavy alloy mechanisms, sinter along with the molten phase or even sinter in the solid state will be provided [47].

Pressed pieces of iron-copper powders, containing less copper than its solubility limit in austenite, can be sintered at a sintering temperature higher than the melting point of copper without forming a molten phase. For example, an alloy of 93% Fe, 7% Cu can be heated very slowly to the sinter temperature of 1150 degrees Celsius so that a solid solution of copper in iron is formed without the formation of a molten phase. Especially if the size of the powder particles is small.

That is, if the diffusion distance is very small, this can be considered as sinter in the solid state due to internal diffusion. If the compacted parts are heated too quickly, sinter conditions will occur along with a transient molten phase. That is, as long as the compressed piece is heated up to the sinter temperature, the melt is formed, but it disappears due to internal diffusion at the same time as the sinter. Iron-copper alloys containing more copper than the solubility limit of copper in austenite at sintering temperature (approximately 7.5% Cu at 1100°C) have been chosen as classic examples for the sintering process along with the molten phase. During the sintering process, the phase melt is stable, the parts are sintered during the freezing interval of the alloy system, and they are inhomogeneous during the entire sintering stage. Sintering temperatures are entirely related to the ceramic-metal system and are related to the choice between solid and liquid phases in sintering. Sampling temperatures of products whose base includes bronze, silver or copper are from 850 to 1050 degrees Celsius (1560 to 1920 degrees of final phase) for cemented carbides 1300 to 1500 degrees Celsius (2370 to 2730 degrees of final phase) [48]. For applications that require fine machining or graining, such as many cemented carbide tools and parts, pre-sintering at 1000 to 1100 degrees Celsius (1830 to 2010 degrees' final phase) is required so that the metal contact points can bond. Find and create enough resistance in the body so that the body can withstand rough machining.

This is done for shrinkable materials that undergo shrinkage during post-sintering. Depending on the density of the fresh object, cermet pieces can shrink and shrink up to 18-25% linearly (45-60%) in terms of volume during liquid phase sintering. In systems with excellent sintering ability virtually all porosity is lost.

During any sintering process, especially during the liquid phase process, many complex metallurgical phenomena occur that depend on the temperature, the atmosphere inside the furnace (hydrogen, neutral gas or vacuum) and the dynamics of the specific metal-ceramic system [49]. A phenomenon observed during the sintering of the WC-CO system lasts for a very long time. When heating the compressed piece resulting from the mixture of tungsten carbide powders in cobalt, a molten phase is formed due to the reaction between them. Therefore, sintering of cemented carbides is an example of sintering with a molten phase. Authoritative scientific papers are available on the base system and its many different alloys.

Sintering mechanism with liquid phase

To introduce the most important characteristics of sintering along with the molten phase in which the heavy alloy mechanism is established, one should refer to the article related to the sintering of heavy alloys of tungsten, nickel, and copper, which can be used in the field of cermet’s. This sintering process along with the liquid phase includes the following characteristics:

- The chemical composition is chosen so that the material remains solid during sintering be soluble in the molten phase.
- The sintering temperature should be as high as possible so that a significant amount of the molten phase is formed. At a temperature higher than that, the density of the part increases rapidly.
- The size of the powder particles that act as the solid phase is important. Powder density increases faster and more completely with fine particles.
- The final density is independent of compaction pressure. In order to reach the theoretical density, the particles are denser under low pressure than when they are under high pressure.
- Microstructure shows grain growth when compared to the particle size of the original hard phase powder. This grain growth can be evaluated and is independent of sintering time and temperature.

When the main hard phase particles are angular (for example, titanium carbide), they can be rounded during the sintering process. However, this is not always the case as some hard corner materials (for example tungsten carbide) appear to have shape memory. That is, they get their shape later. During the re-deposition of the elements dissolved in the liquid phase during cooling, the crooked corner pieces become the hard phase particles of these materials. In the analysis of the sintering mechanism along with the liquid phase to increase the density and growth of solid particles, three steps are considered:

1- Melt flow stage or rearrangement

In this stage, after the melt appears and following the collapse of the melt bridges between the particles and the rearrangement of the solid particles, which means that they slide on each other, the density increases due to the pressure caused by the capillary property.

2- Re-sediment solution stage or matching stage

In this stage, the density increases as the solid phase particles grow due to dissolution and redepositing of the consolidation process.

3 - Sintering stage in solid state

Only at this stage, a slow increase in density is possible.

Furnaces

Sinter furnaces are offered in three sections. Continuous furnaces for sintering structural components, automotive bearings in bulk and sometimes cemented carbides in protective atmospheres. Non-continuous furnaces for sintering compacted parts from powders of refractory metals and their alloys, compacted parts from carbide cemented in protective atmospheres to other metal powders that are impractical or uneconomical to sinter them in continuous furnaces. Vacuum sintering furnaces, including continuous and non-continuous types, are used for sintering construction parts, cemented carbides, refractory metals and alnico magnets. High temperature continuous sintering furnaces have been used for many years in the cemented carbide and refractory metal industries.

They are equipped with a hydrogen atmosphere or protective atmosphere with a low dew point (the temperature at which water vapor condenses) to reduce oxygen in the parts and prevent them from oxidizing. And they are used in large numbers. Non-continuous vacuum furnaces have also become very popular and widespread in the last 30 to 40 years. When there is a choice between continuous pusher type furnaces and discontinuous type furnaces, equipment and operating costs determine the type. One of the main reasons why vacuum sintering is interesting is that the energy required to provide the shielding atmosphere is really high and may be more than half of the total energy required for sintering. Vacuum sintering significantly reduces the total energy consumption of the process.

The optimum vacuum level during liquid phase sintering varies and depends greatly on the solid phase bonding system applied. In the design of some advanced furnaces, a hydrogen atmosphere is used for the initial operation, which can be changed to a vacuum to pass to the next stage in the sintering cycle. Others create an alternating pressure cycle of hydrogen followed by vacuum.

Static cold pressing

Cold pressing methods for cermet powder mixtures are generally the same as known powder compression methods used in conventional powder metallurgy. The small parts of cermet required due to their large amount are compressed in special hard metal molds by automatic press machines with opposite moving jaws. Depending on whether they are solid or granular, the molds are shrink-wrapped in strong, hardened, heat-treated steel housings. The automatic compaction cycle consists of filling the molds with powder, pressing the powder, exiting the compacted object and separating it. Two methods are used to remove the compacted object from the mold. In the first method, the lower jaw moves up and pushes the end of the part under pressure to the surface of the mold above it. In the second method, the mold is pulled down until the lower jaw is next to the upper edge of the mold. The second method is preferred by many experts. Because this method allows the construction of the device to be smaller and with cheaper tools, and also because more care is taken during the removal of the fragile compressed part.

Another type that has received attention, especially for the compression of brittle cermet's, is a method called fixed-jaw compression. In this method, the powder is compressed on the fixed jaw with the upward movement of the lower movable jaw. Then, the fixed jaw is removed so that the compressed part can be removed with the range of motion towards the top of the lower jaw. Because this cold pressing method is a single-movement pressing method, the movement of only one press jaw is acceptable only for relatively narrow parts. Still, in some places, single-jaw presses reduce machine costs. In addition, the exit path of the piece has been reduced to the minimum possible, which is an important factor for fragile cermet's. Medium to large rectangular parts are kept with hydraulic press machines and inside the molds all sections and side by side by powerful steel molds. These molds are able to react to the large internal forces applied to the powder mass and transfer it radially to the mold sections. Often, after the cycle is complete the molds are opened to carefully remove the fragile compressed cermet's. For round parts, it is preferable to use double-sided hydraulic presses with internal extruding function.

These presses can use one of two externalization methods

- If the mold is mounted on a hydraulically active floating plate, a single press function will easily provide the effect of a double press. In this case, the removal is done by the pressing method.
- When a powerful double press (with two movable jaws) is available (obviously this machine must be heavier and more expensive than a single-jaw press), the mold can be mounted on a stationary plate. The compressed part is removed when the lower jaw rises to the level of the edge of the mold when the pressure cycle is completed.

Cold pressing of cermet with simple shapes generally gives good results when using suitable oil powder mixtures, well designed tools and uniform pressures. Even when the pressed parts are fragile, they should be strong, the sand resistance should be sufficient, and the edges should be well formed, and it should not have cast swelling (thin non-metallic layer in the cast object) or other internal defects. In connection with the composition of cermet, problems with the compression process can occur when the equipment or processes need to be modified. In general, the larger part of the hard phase causes the most problems during the compression process; These problems are not revealed until after sintering. You can also expect more problems with iron, nickel or cobalt based cermet's than with softer types such as most aluminum based malleable compounds. Larger parts, both in terms of diameter and height, make the manufacturing problems more severe. Air voids, bridging (freezing of the charge in a part of the mold before the underlying metal freezes), casting swelling, back-to-back voids, and varying density along the length of the compacted part are just a few of the problems encountered in compression. Cermet's are treated coldly. Some of these problems can be solved by adding more lubricant to the mixture, by adding to the top of the compression mold, or by slowing down the compression process. Lubricating the mold walls between the pressed parts often helps to eliminate problems with the pressed part being ejected. Proper preloading of the mold and covering the mold for compression are other methods that help to solve the problems. Even for the simplest shapes, such as a cylinder or a square with a blank surface, not all problems can be solved by the usual cold pressing method. This is one of the reasons why powder metallurgy (P/M) specialists use more complex forming processes to make different products than others.

Cold hydrostatic (all-round) pressure action

High-quality cermet compacts require uniform density at all points. In this method, the pressure is applied simultaneously and uniformly from all directions to the center of gravity of the powder mass. While all the friction of the powders with the mold wall has been completely removed. In order to compress simple or even relatively complex shapes with this method, dry powders are poured into a flexible mold and filled. The powders are crushed and the air is removed by shaking. The mold is then completely closed and placed inside a cylindrical vessel made of reinforced steel that is filled with a fluid. After the container is closed, the hydraulic pressure increases, by which the powder is compressed into the mold. Two hydrostatic compression methods are used to compress cermet's, which are the wet bag method and the dry bag method. In the wet bag method, one or more molds filled with powder are placed in a hydrostatic pressure vessel. The mold filled with flexible powder is placed inside a perforated container for its storage. Inside the container, the mold containing the powder is completely surrounded by hydraulic fluid. Depending on the size of the container and the mold itself, often a number of molds can be placed inside the container and compressed at the same time.

The whole process of loading the container with one or more molds, increasing and maintaining the pressure, and opening the container and emptying it is relatively slow. In addition to the fact that filling the mold, compacting the mold, and loading the molds into the pressure vessel and unloading and removing the pressed parts after the process is complete are slow, the manual processes required must be precise and detailed. The dry bag compression method uses a flexible mold that is completely enclosed and sealed in a pressure vessel. After the mold chamber is filled with a controlled amount of powder, the cover plate is closed and hydraulic pressure is applied. After, the pressure is released, the part is removed and a new cycle begins again. The dry bag pressing method has a much faster production process than the wet bag pressing method, and it also has the possibility to be automated. Most of this technology has been developed to produce ceramic parts or close-to-grid shapes. For example, a car spark plug body. Installation of any dry form requires special engineering and investigation.

Advantages and disadvantages

Hydrostatic pressure brings these benefits

- The compressed pieces of cermet have the same density regardless of size and shape.
- The wet bag method works well for large parts and is often the only practical way to compress such parts.
- Narrow parts with large length-to-section ratios can be worked with this method.
- The price of the mold is low compared to rigid pressure molds. Therefore, small production quantities can be produced economically, especially with the wet bag method.
- Lubrication is not needed or is little needed.
- The process is well suited for research and development work.

The disadvantages of hydrostatic pressure are as follows

- The control of dimensions to be pressed is limited. The mold design must accommodate axial and radial shrinkage because hydrostatic pressure acts to cause shrinkage after sintering.
- Surfaces under pressure are less flat than these surfaces in the method of sprung molded parts.
- A very large liquid phase is required in the sintering or cladding stage before hydrostatically pressed cermet parts can be heated by isostatic pressing.
- The cost of equipment is high and the use of equipment can be small.
- The labor cost is relatively high.
- Generally, the production rate is significantly lower in isostatic pressing.
- Surfaces of parts pressed by isostatic method are not smooth.
- The life of elastic molds used in isostatic pressing is less than solid steel molds or cemented carbides.
- For cermet structures that have a high load of hard phase or relatively hard metal and alloy binders and are difficult to press, cold hydrostatic pressing is

often a convenient and available manufacturing method, and sometimes the only reliable method for working with certain compositions.

Conclusion

In general, cermet's were used for applications such as cutting tools. About 45 years ago, they also played a role in other applications such as propulsion systems (forward thrust). These materials are expected to have ceramic properties such as refractory behavior, resistance and corrosion stability, usefully with the base part of a metal that has properties such as high ductility and thermal conductivity will cooperate, and some new excellent materials for applications with very high temperatures will be produced. Unfortunately, despite many efforts in the United States and Europe during the 1950s, these goals were not achieved. The amount of malleability and hardness obtained from the metal adhesive part remained insufficient for many vital applications such as turbo jet engine (turbine jet aircraft) and gas station jet blades or nozzle blades. In other cases, however, cermet's have improved applications for materials used in engineering, especially in tools based on titanium carbide (TiC) or titanium carbonitride (TiC, N) and in some types of fuel elements. Nuclear cermet's based on uranium dioxide have the possibility to be converted into nuclear fuel as well as those based on uranium carbide (UC). Cermet's based on zirconium boride (ZrB_2) or silicon boride (SiC) and others that include aluminum oxide (Al_2O_3), silicon dioxide, boron carbide (B_4C) or refractory compounds with diamonds have the same properties.

Some are economically used in a wide range of applications, including hot machining tools, shafts and bodies in metal tube covers, valve components and cover parts, tubes and fuses exposed to very high temperatures, rocket engine components, clamps. Furnace and its main elements include grinding wheels and cermet's including diamonds and saw teeth are used. One of the important applications of cermet's includes cutting tool materials that use TiC or TiC, N as a highly refractory phase. Also, molybdenum carbide (MO_2C) and other carbides are made based on the formulation of these cermet's. The resistance to corrosion and wear of the edge and wall of tool materials made of TiC and TiC, N cermet is better than the same properties of conventional cemented carbide tools (which is cobalt mixed with tungsten carbide). Compared to ceramic cutting tools, this cermet's allow heavy cutting at high speeds, resulting in more metal removed at levels comparable to tool life. Cermet's clearly have cutting tool material properties that can bridge the gap between conventional cemented carbides and ceramics. One of the industrial applications of cermet is mechanical regeneration. One of the results of CM inspections and especially oil analysis is the presence of a high percentage of metal in the analyzed oil and indicates the presence of metal corrosion that occurs on the involved surfaces. Cermet, which is a combination of ceramic and metal, is made according to a new technology that has been registered in several countries of the world, which is injected into corrosion areas with lubricant (oil or grease). If the environment has the necessary energy i.e. temperature and pressure for the reactions, cermet causes the metal particles in the lubricant to return to the corroded surfaces and over time the corrosion is repaired and in addition a highly polished surface is obtained. In this method, there is no need to stop the equipment and the repair is done during the normal operation of the equipment. The term "Revitalization" is derived from the Latin word (vita) which means life and means revival. The discovery of the regeneration phenomenon is based on exclusive physical and chemical processes that occur under special conditions in the friction zone. Cermet, which is a combination of two names, ceramic and metal, and contains a type of raw material and a catalyst, spends the extra energy from friction, heat and pressure to form a new surface on the parts. The regeneration process ends as soon as the geometric shape of the part (or parts of the device) is restored and returns to its original shape. By performing the regeneration operation, the parts that are in contact with each other are fully adapted to each other. After revitalization, the surfaces of the parts are polished like glass. The thickness of these reconstructed layers on the worn parts of pumps reaches several microns in the case of car engines to tens of microns and on gears to hundreds of microns.

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