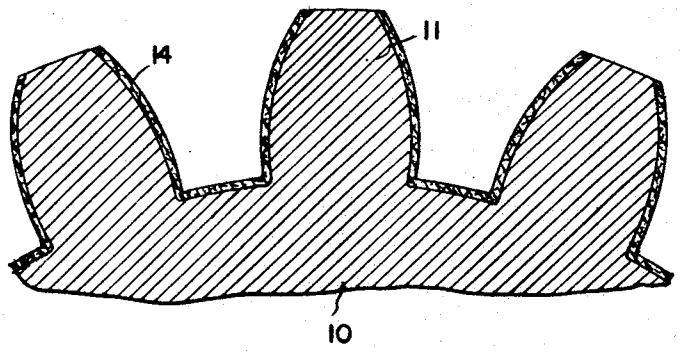
Feb. 10, 1970 D. W. DANIEL 3,494,752

METHOD OF MANUFACTURING METAL BONDED ABRASIVE GEAR HONES

Filed March 4, 1968

FIG.1.



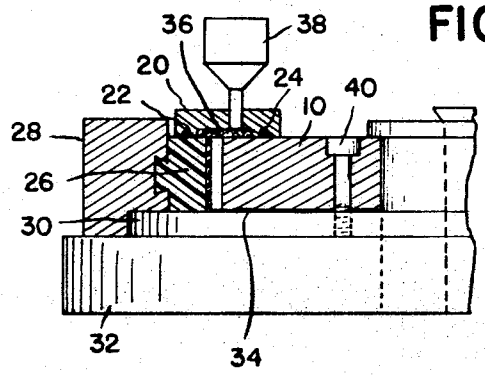
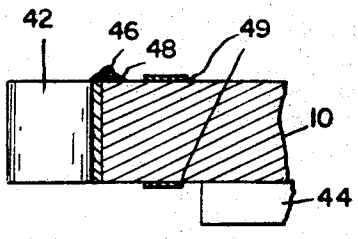


FIG.2.

FIG.3.



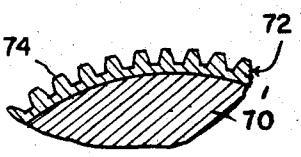


FIG.5.

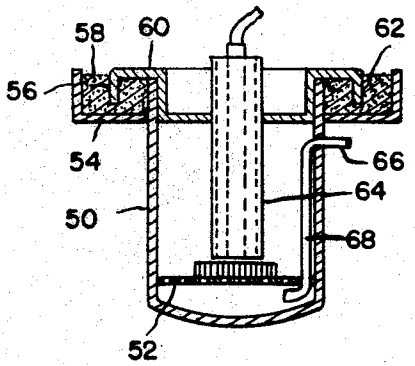


FIG.4.

INVENTOR.
DAVID W. DANIEL
BY Whittemore, Hulbert & Belknap
ATTORNEYS

United States Patent Office 3,494,752 Patented Feb. 10, 1970

3,494,752

METHOD OF MANUFACTURING METAL BONDED ABRASIVE GEAR HONES

David W. Daniel, Birmingham, Mich., assignor to Lear Siegler, Inc., Santa Monica, Calif., a corporation of Delaware

Continuation-in-part of application Ser. No. 313,240, Oct. 2, 1963. This application Mar. 4, 1968, Ser. No. 721,535

Int. Cl. B24d 3/08

U.S. Cl. 51—293 27 Claims

ABSTRACT OF THE DISCLOSURE

A metal bonded gear hone is provided by dissipating an interim binder, leaving behind on the surfaces of gear teeth a mixture of abrasive particles bonded together and bonded to the gear teeth by metal.

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of my prior copending application, Ser. No. 313,240, filed Oct. 2, 1963, and now abandoned.

FIELD OF THE INVENTION

The present invention relates to gear honing tools in the form of a metal gear having the surfaces of the teeth provided with abrasive particles supported and bonded to the tooth surfaces of the tool by metal. Hones of this type have been made by a process in which a mixture of molten metal and abrasive particles is sprayed on the teeth. This is very inaccurate and does not lend itself to careful control of tooth profile.

SUMMARY OF THE INVENTION

The present invention is characterized in all embodiments by the use of an interim binder. By this term is meant a binder which may be applied in fluid form as a molded coating to teeth of a metal gear so that it may be molded into accurately controlled shape and then caused to set. The article may then be removed from the mold and the cured binder will retain its molded shape.

In one embodiment of the invention the binder, when it is applied in fluid form to the teeth of the gear in a surrounding mold cavity, contains a minimum amount of interim binder and is composed for the most part of a mixture of metal powder and abrasive particles. After removal from the mold the coated gear is heated to melt the metal and to cause the interim binder to be dissipated.

In an alternative method the material cast as a coating on the teeth of the gear is a mixture of abrasive particles and the interim binder. After the interim binder has been hardened the gear is removed from the mold and the metal is provided adjacent the edge of the teeth. The gear is now heated, causing the interim binder to be dissipated and causing the metal to melt and flow into the voids in the coating which remains on the teeth of the gear.

Best results have been obtained when the interim binder is polyvinyl alcohol, hereinafter referred to simply as PVA. However, generally similar results are obtainable using sodium silicate as the interim binder, and satisfactory results have been obtained using an aqueous paste formed of spun silica sold under the trade name Cabosil. This material is produced by finely dividing and condensing melted silica and appears as extremely small white flakes. The material is a thixatropic agent and produces, when employed with the abrasive particles or the mixture of abrasive particles and metal powder, a mixture which may be hardened.

It is accordingly an object of the present invention to provide a method of making metal bonded hones characterized particularly in the employment of an interim binder which permits casting a coating on the teeth of a gear to exact form followed by a subsequent step of heating the cured or hardened binder to cause it to be completely or substantially completely dissipated from the tooth coating.

More specifically, it is an object of the present invention to provide a method of producing the hone described in the preceding paragraph which comprises centering a metallic blank with respect to a mold having the required tooth configuration, with the flanks of the tooth surfaces of the mold and blank spaced apart a uniform distance, as for example about .020 inch, thereafter tightly packing abrasive particles within the space leaving voids as determined by the size and shape of the particles, thereafter saturating or wetting the assembly of abrasive particles between the mold and metal blank with an interim fluid binder such for example as a solution of polyvinyl alcohol, baking the complete assembly to solidify the binder, thereafter withdrawing the blank with its tooth flanks coated with the baked mixture of binder and abrasive particles, positioning the metallic matrix or brazing material on the coated blank adjacent the coated tooth flank surfaces, and finally heating the assembly to a temperature, for an interval of time, and in a controlled atmosphere sufficient to eliminate the interim binder, to melt the metallic matrix material, and to cause the matrix material to flow into the voids between the closely packed abrasive particles left by the elimination of the interim binder thereby brazing the abrasive particles to each other and to the metal blank.

It is a further object of the present invention to provide a method as described in the preceding paragraph in which, in order to produce a more closely packed array of abrasive particles, a mixture of abrasive particles of different sizes is employed.

It is a further object of the present invention to provide a method as described in the foregoing in which the abrasive particles are tungsten carbide.

It is a further object of the present invention to provide a method as described in the foregoing in which the spacing between the confronting flank surfaces of the mold and blank are separated by approximately .020 inch and completely fill the spaces between the confronting tooth flanks with abrasive particles, approximately four parts by weight of the particles having a grit size of at least 170 and one part by weight of the particles having a grit size of 270 or less.

It is a further object of the present invention to provide a method as described in the foregoing which comprises the steps of washing the abrasive particles, preferably in carbon tetrachloride, prior to introducing them into the space between the tooth flanks of the mold and blank in order to improve bonding between the abrasive particles and the binder.

It is a further object of the present invention to provide a method as described in the foregoing in which the matrix material is in wire form at the upper surface of the blank directly adjacent to the bottoms of the spaces between adjacent teeth thereon.

It is a further object of the present invention to provide a method as described in the foregoing in which the metal matrix material is positioned on a side surface of a coated blank in the form of wire segments, retaining the segments in place by metallic paste.

It is a further object of the present invention to provide a method as described in the foregoing in which the metallic matrix material is at least principally formed of

copper and preferably is in the form of a copper alloy of approximately 94–95% copper and the remainder preferably tin.

It is a further object of the present invention to provide a method as described in the foregoing in which the interim binder is eliminated and the metallic matrix material is melted by heating the assembly in a sealed retort in the presence of hydrogen gas.

It is a further object of the present invention to provide a method as described in the foregoing in which the fluid interim binder is applied by differential pressure and is caused to flow into and through voids between the abutting abrasive particles packed in the space between confronting surfaces of tooth flanks of the mold and blank.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawing illustrating preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a fragmentary sectional view of a portion of a metal bonded hone constructed in accordance with the present invention.

FIGURE 2 is a diagrammatic sectional view through an assembly of parts illustrating the manner of applying the binder to the abrasive particles.

FIGURE 3 is a fragmentary view illustrating the manner of applying the metallic matrix material to the coated blank.

FIGURE 4 is a diagrammatic view illustrating the manner of subjecting the assembly to heat in a hydrogen atmosphere.

FIGURE 5 is a fragmentary sectional view of a hone of fine pitch.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In recent years a new practice in the finishing of work gears known as honing has achieved very considerable commercial importance. The honing of gears is carried out by rotating a work gear in mesh, preferably at crossed axes, and in pressure contact with a gear-like honing tool while providing a relative traverse between the rotating gear and honing tool in a direction which occupies a plane parallel to the axes of both the gear and tool so as to distribute the honing action from end to end of the gear teeth. Best results have been obtained when the hone has its tooth portion formed of a relatively hard but slightly yieldable and highly resilient plastic material. Epoxy resin has so far proved to be the most efficient material for this purpose. The resin has embedded therein a multiplicity of abrasive particles, these particles being separated and thus capable of relative movement and independent yielding.

Efforts have been made to produce honing tools which, while of inferior accuracy, are relatively inexpensive and are satisfactory for removing the worst of nicks and burrs appearing on finished gears as a result of mishandling. Honing tools of this nature have been made by spraying a mixture of metal and abrasive particles onto the flanks of gear-like blanks where the sprayed metal adheres to the metallic tooth surfaces. With this method it is of course impossible to maintain anything like exact tooth form on the finished tool.

With this background, applicant has developed a method of producing a hone in which abrasive particles are bonded by metal to the tooth flanks of a metal gear-like blank, and to provide this metal bonded abrasive material so as to control the final tooth form with exceptional accuracy, and to control the thickness of the deposited abrasive material with a corresponding accuracy. Such a hone is illustrated in FIGURE 1, comprising the metal gear-like body **10** having teeth **11** of reduced chordal thickness and provided on the flanks thereof with a layer indicated at **14** composed of a solid array of abrasive particles having voids formed therebetween as a result of irregular size and shape of the abrasive particles, the voids being completely or at least sufficiently filled with a metallic matrix to bond the particles in place.

Briefly described in general terms, the method has been successfully carried out in the following steps: A steel blank is hobbed into gear form provided with teeth having a chordal thickness of approximately .040 inch less than the ultimate desired chordal thickness on the finished tool. If the honing tool is relatively fine pitch the outside diameter of the blank is reduced by a small amount as for example, .002 inch, so that the metal matrix which subsequently bonds the abrasive particles to the flanks of the teeth will span the crests of the teeth. The tooth surfaces to which the abrasive material is to be applied are then shot blasted on the profiles of the teeth and on the edges of the gear for about an inch back from the roots of the teeth. Excellent results are obtained when this shot blasting is carried out with 120 grit chilled shot using 100 pounds pressure. This shot blasting breaks up the smooth surfaces and facilitates the flow of the melted metallic bonding material or matrix during the final operation. It also reduces heat reflection from the blank, thus speeding up heating of the blank.

An epoxy mold is provided having the exact desired final configuration of the hone and the tooth surfaces of the mold are waxed or provided with some other suitable parting agent. The steel blank is positioned in the mold in properly centered relation. For this purpose the mold and blank may conveniently be supported on apparatus of the type illustrated in Daniel Patent 3,059,278 so that the blank and mold are in exact concentricity. At this time, due to the initial dimensions of the steel blank, there will appear a uniform space between the confronting surfaces of the flanks of the teeth of the blank and the mold of approximately .020 inch. As previously stated, this space in a substantially reduced amount may extend across the crests of the teeth of the blank. Preferably, the steel blank has its teeth hobbed to a depth such that a substantial space extends across the crests of the teeth of the mold adjacent the roots of the teeth of the blank and this space may be of a thickness comparable to that appearing between the tooth flank surfaces.

The assembly as just described, is now subjected to vibration and conveniently, this may be accomplished by supporting the assembly on a table which is rotated and vibrated. Excellent results have been obtained when the vibration is at a rate of about 5000 cycles per minute.

During vibration abrasive particles are now introduced into the continuous space between the tooth profiles of the blank and those of the mold. The exact size of the particles and the material of the particles may be varied. However, particles of tungsten carbide exhibit superior qualities and adherence in conjunction with the available metallic matrix materials, and accordingly, it is preferred to use abrasive particles of this material.

Better adherence or bonding between the interim binder and particles is obtained if the particles are washd to remove fine dust therefrom. Best results have been obtained by washing the particles with carbon tetrachloride. It is found that particles which appear to be perfectly clean and of uniform size, nevertheless when washed in carbon tetrachloride give up a quantity of finely divided material sufficient to discolor the carbon tetrachloride very appreciably, thus demonstrating the desirability of this step.

It is essential to have the abrasive particles packed as tightly within the narrow space provided as is physically possible. It will of course be appreciated that since these particles are of irregular configuration, when they are tightly packed into the space there nevertheless remains a multiplicity of voids between the adjacent and contacting particles, the total volume of voids being of course dependent upon the size and shape of the particles. However, it is found that a denser packing of the particles is

possible, thus facilitating the filling of voids by the metallic matrix, as will subsequently be described, when a mixture of particles of predetermined different sizes is employed. The principle explaining this phenomenon is of course obvious since it will be apparent that relatively small particles can occupy voids formed between relatively large particles without increasing the volume occupied by the relatively large particles.

Excellent results are obtained using approximately two parts by weight of tungsten carbide particles of 140 grit size, two parts by weight of 170 grit size, and one part by weight of 270 grit size. The smaller particles evidently occupy voids between adjacent larger particles to some degree, thus increasing the density of pack of the abrasive particles.

It may be noted that efforts to force the particles mechanically into the narrow space have met with no success since an attempt to force the particles into the space simply jams the particles and insures that the spaces will not fill.

As an alternative to filling the confined spaces by employing vibration, it is possible to entrain particles in an air stream moving through the confined space in conjunction with means equivalent to a screen at the opposite side or end of the space to permit passage of air but to arrest movement of the entrained particles.

Following the step of filling the confined spaces between the flanks of the teeth of the mold and blank as completely as possible, there follows the step of providing a fluid binder for the particles. This binder must be fluid so that it may be sucked or applied under pressure so as to completely wet all abrasive particles and the metal body in the coating area. It also must have the property of hardening sufficiently upon moderate baking to provide a firm coherent layer adhered sufficiently strongly to the flanks of the teeth of the blank to permit withdrawal of the blank with the coating intact from the mold.

Finally, it is desirable for the binder to have the property, upon being subjected to an elevated temperature for a sufficient interval, to be completely eliminated while a metallic matrix melted under a higher sequentially applied temperature flows in to replace the binder material thus eliminated.

For this purpose it is desirable to select a material which can be completely eliminated by the application of heat and therefore organic binders appear preferable. It is selected from materials which are sufficiently fluid at normal room temperatures to permit application conveniently to the array of packed abrasive particles. It must bake under moderate heating to provide a relatively hard layer which can thereafter be substantially completely eliminated by increased temperatures from the voids. Thereafter, while the particles retain their accurately formed condition, the metallic matrix material melts and flows by capillary action and otherwise into the voids between abrasive particles.

The material which appears to conform most closely to the foregoing physical requirements is an aqueous solution of polyvinyl alcohol, commonly identified as PVA. However, satisfactory results have been attained using sodium silicate solution available commercially as "water glass."

The next step in the manufacture of metal bonded hones is to paint the PVA solution over the upper edge portions of the blank in a continuous annular zone thereabout including the roots of the teeth and somewhat radially inwardly therefrom. This wets the surface and permits a later application of the PVA solution to flow more readily completely around the blank.

In the application of the PVA solution to wet the closely packed abrasive particles, the fluid binder may be supplied to the upper surface and sucked through the packed array of abrasive particles by the application of suction therebelow. However, a quicker and better control of the flow of the binder material is obtained when a pressure ring **20** is provided which includes radially inner and outer sealing O-rings **22** and **24**. The pressure ring **20** is clamped concentrically over the metal blank **10** and the mold **26**. The mold **26**, as disclosed in the prior Daniel patent previously referred to, is carried by a mold ring **28** which is centered on a pilot **30** provided on the support **32**. For the present operation shims indicated at **34** are positioned between the top of the pilot **30** and the blank **10** to provide for flow of binder material. Shims having a thickness of .001 inch are satisfactory.

The pressure ring **20** is provided at its lower side with a continuous downwardly facing annular groove or channel **36** of a width sufficient to overlie the space defined between the teeth of the mold **26** and the blank **10**. Liquid binder material is introduced into the channel **36** through a fitting **38** and excellent results have been obatined when the liquid binder material is applied under a pressure of approximately 20 p.s.i. The application of fluid binder material is continued until the binder material is visible through bolt holes **40** present in the blank. With this arrangement it is found that the packed assembly of abrasive particles can be filled or completely wetted with binder material in a short interval, as for example, two or three minutes.

The assembly of the mold ring **28**, the mold **26**, the blank **10**, the support **32**, **30**, the abrasive particles, and the binder material is baked for approximately eight hours at 220 degrees Fahrenheit. This has the effect of causing the PVA to dry thoroughly and to set so as to form a strong self-supporting mixture of particles and binder on the surfaces of the teeth.

The baking operation is conveniently carried out in a combined heating and refrigerating chamber so that upon completion of the baking cycle the chamber is subjected to a reduced temperature as for example, approximately 50 degrees Fahrenheit. This causes the epoxy mold to be perfectly rigid and to insure that the coating made up of the abrasive particles and the binder is hard and solid.

Thereafter, the support **30**, **32** is removed from the mold assembly, the blank is pressed out of the mold, and the abrasive material and binder, which separates freely from the mold surfaces due to the provision of the parting agent supplied, remains firmly bonded thereto. It is found in practice that at this time the abrasive coating is smooth and generally continuous, even including sharp two-surface and three-surface corner intersections. Dimensional and profile checks of the coated blank at this time conform with remarkable closeness to similar checks of the master used for the initial formation of the epoxy mold.

At this time the problem is to eliminate the organic binder and to replace it with a metal matrix which will permanently bond the abrasive particles together and to the tooth surfaces of the hone. It has been determined that adequate bonding to produce highly useful hones results from the use of pure copper. This copper may be applied in the form of a paste or it may be applied in the form of a wire, or sections of wire distributed in a circle around the upper surface of the hone assembly substantially at the roots of the teeth. Where wire is employed rather than paste, it is desirable to employ sufficient paste in conjunction with the wire to retain it in proper position.

In FIGURE 3 there is shown a fragmentary section of the blank **10** to which the coating of abrasive particles and binder is applied, as indicated at **42**. At this time the blank **10** is positioned flat on a support **44** and on its upper surface is provided the metal wire **46** which extends around the blank substantially at the zone of the roots of the teeth. The wire **46** is retained in this position by sufficient metallic paste **48** to fit it in position.

In order to reduce flow of the melted copper or brazing material over the entire upper surface of the blank,

a mask **49** is provided. This mask is formed by painting or otherwise applying a "stop" which has the function of acting as a barrier against flow of the melted cuprous material. Stops having this function are available on the open market. A suitable stop for this purpose is sold by McKesson & Robbins under the trade name "Merco" identified as a copper mask material type A.

Instead of employing copper and a copper brazing paste, a hone having somewhat improved wearing properties is obtained by using a metallic matrix material which is essentially nickel. This material is available from Wall Colmonoy Company in powered form, essentially a powdered nickel alloy in which nickel is the principal metallic material. In using this material the powdered nickel alloy was mixed with PVA and hardened to produce a solid body from which pieces were cut equivalent to wire segments of the type employed in the use of copper.

When employing the powdered nickel alloy the tooth spaces of the hone assembly were completely filled with the nickel alloy and after the final heat treatment, subsequently to be described, it was desirable in some cases to perform a second operation in which additional nickel alloy powder was packed into the tooth spaces of the hone so as to complete filling of the voids between abrasive particles.

Finally, the best results have been obtained when the metallic matrix material is employed in wire form and comprises an alloy of approximately 94.3% copper, 5% tin, .2% phosphorous, and .5% other materials. In the production of hones having a pin size diameter of approximately 8½ inches this wire is employed at ⅛ inch diameter and is cut so as to provide lengths extending approximately 90 degrees around the zone of the root diameters of the hone. This wire is retained in place by a copper brazing paste.

The final operation, which will of course vary slightly in accordance with the particular metallic matrix material employed and may also require variation in accordance with the density of pack of the abrasive particles and for other reasons, is heating to a temperature and for a period sufficient to eliminate the organic binder, to melt the metallic matrix material, and to cause the melted matrix material to flow by capillary action or otherwise into the voids left by the elimination of the binder.

In the case of the hone using the nickel alloy as the metallic matrix, the hone was heated to 1900 degrees Fahrenheit over an interval of about 45 minutes and was held at 1900 degrees Fahrenheit for approximately 30 minutes.

Heating was in a retort and a hydrogen atmosphere was supplied during the high temperature portion of the heat treatment.

The apparatus for soaking the hone assembly at a high temperature in a controlled atmosphere is illustrated in FIGURE 4. In this figure there is shown a retort **50** having a grate **52** adjacent its bottom and provided with an open top. Surrounding the retort near its open top there is provided an outwardly extending flange **54** with an upturned edge portion **56** defining a channel **58** which in use is filled with sand to provide a seal.

A cover **60** is provided for the retort including a downturned peripheral flange **62** adapted to enter into the sand received in the channel **58**. The cover **60** includes a tubular well **64** for the reception of a thermocouple. A tubular fitting is provided as indicated at **66** for connection to means for supplying the purging gas and connects internally to a tube **68** dumping into the bottom of the retort below the grate **52**. The hone assembly to be heat treated is positioned on the grate and the atmosphere is controlled by admission of gas through the fitting **66**, the gas continuously escaping through the sand seal. When employing a hydrogen atmosphere, air is purged from the retort by first causing nitrogen to flow therethrough and the flow of hydrogen is not initiated until all oxygen has been expelled and preferably, a substantial increase in temperature in the retort has been noted. For example, in practice, nitrogen was shut off when the temperature as observed by the thermocouple was 1300 degrees Fahrenheit, after which hydrogen was started through the retort at a flow of about ten cubic feet per hour.

The method so far described in detail involves the formation of an assembly of abrasive particles between tooth surfaces of a blank or core member and covering tooth surfaces of a mold. Where the hone is in the form of a fine pitch gear, as for example a gear having a diametrical pitch of **32**, the size of the teeth precludes the formation of a coating thereon. In this case the blank may be provided in the form of a steel cylinder having a smooth cylindrical outside diameter. This blank is positioned concentrically in a mold, the inner surface of which is formed to the exact tooth contour desired in the finished mold. The outside diameter of the blank is slightly smaller than the inside diameter of the mold so that when the spaces therebetween are completely packed with abrasive particles, the particles form the entire tooth structure of the hone and provide a continuous connection between the teeth. A hone constructed in accordance with the foregoing is illustrated in FIGURE 5 where a portion of the cylindrical blank is illustrated at **70** and the abrasive grains received in or bonded together by the metal matrix are indicated generally at **72**. In this case it will be observed that the teeth **74** are so small that it would not be practical to attempt to form them by providing a coating on similarly shaped teeth on the core **70**.

In the application of the interim binder such as PVA or sodium silicate, it has been found that the amount of the binder material received in the closely packed abrasive particles is not highly critical. It appears to be perfectly satisfactory to apply the binder in such a way as to insure substantially complete filling of all voids in the abrasive particles by the binder material. However, it has been found that blowing execess material from the voids, or accomplishing similar results by the application of suction, does not impair the effectiveness of the operation. Evidently, if the bonding material thoroughly wets the abrasive grains so that it is present at points of contact between adjacent grains, the bonding action is sufficient. The presence of excess bonding material, filling the voids is not objectionable but it apparently is not required.

The quantity of the metal matrix which is caused to flow into the porous assembly of abrasive grains is also not critical. It is of course essential that the melted metal matrix flow in such a way as to produce a metallurgical and/or firm mechanical bonding or interlocking of all abrasive grains. However, this appears to be accomplished while substantial voids may remain in the abrasive material. Thus, it is apparently sufficient if enough of the melted matrix material flows into the assembly of abrasive grains to insure that all grains are connected by the matrix to the adjacent grains or to the adjacent surface of the core. On the other hand, there appears to be no objection to providing the metal matrix in a quantity sufficient to effect substantially complete filling of the voids. It has been noted that the metal matrix material may be provided in successive steps so that if insufficient metal matrix material is provided in the first operation, additional metal matrix material may be added in a subsequent operation. Alternatively, it has been noted that if initially excess metal matrix material is provided, the material apparently completely fills all voids in the assembly of abrasive grains and an excess material may accumulate in spaces between the teeth of the hone or at the underside of the hone. This excess material may be removed mechanically and the

hone again subjected to the heating operation which may have the effect of permitting additional metal matrix material to bleed out of the abrasive assembly.

The foregoing method depends for its success upon the rather surprising ability to retain the abrasive particles in the shape applied thereto by the mold as a result of the presence of the interim binder therein, and thereafter, while the core with the applied abrasive material is separated from the mold, causing the melted metal matrix material to flow into voids between the abrasive grains. When the interim binder material is PVA, this binder material is substantially eliminated during the heating of the hone assembly to the temperature sufficient to insure the melting of the metal matrix material. Nevertheless, the binder or its residue is effective to retain the abrasive grains against shifting at this time and to preserve the accurately conformed surface profiles of the teeth. It has been found that the present method enables the production of hones in which the teeth are within one or two thousandths of an inch of predicted dimensions, and in which the tooth profile is well within accepted limits.

In some cases it is desirable to employ a different metal for bonding the abrasive particles together and for bonding them to the surface of the gear teeth. A metal particularly suitable for this purpose is a chrome nickel alloy available under the trade name "Nicrobraze." This material contains approximately 6½% chromium, 4.5% silicon, 3% boron, 2.5% iron, 1.5% copper, and the balance nickel. This material is not available in wire form and hence the method as previously described is not available when using this material as the metallic binder. However, it is possible to employ a method which retains the advantages inherent in the use of the interim binder, as will now be described.

In carrying out this method of powdered chrome nickel alloy and abrasive particles is mixed with the interim binder, preferably PVA, and the PVA is provided only in sufficient amount to permit the mixture to be formed. The material is then formed into a thin coating which is dried, and thereafter broken up, ground and sieved to provide a mixture of particles somewhat coarser than the abrasive particles which are 140–200 mesh, and coarser than the powdered metal which is 60–80 mesh. The proportion of the metal binder to the abrasive particles, normally tungsten carbide, is approximately 3/2.

This powdered material containing both the metal and the abrasive particles is packed into a mold surrounding the teeth of a metal gear-like body to provide a coating which may be approximately .020 inch thick. This material after it has been packed tightly into the mold is saturated by adding liquid PVA, after which the material is heated to cause it to set and is removed from the mold.

Thereafter, the metal body with the coated teeth is heated to a temperature sufficient to melt the powdered metal and to completely dissipate the interim binder. The metal forms a matrix ruggedly supporting the abrasive particles and forming a layer which is permanently and solidly bonded to the surface of the teeth of the gear body. Moreover, while the interim binder has been dissipated, it is found that the metal bonded coating is substantially impervious. Most important however, it is found that the surface configuration of the metal bonded hone after the interim binder has been dissipated and the metal melted to bond the abrasive particles and cooled to final form, is substantially identical to the tooth surface of the mold in which the coating was initially shaped.

The present method produces an abrasive coating in which the abrasive particles are in contact with each other, thus establishing a structurally continuous material with direct particle-to-particle contact. Due to the memner of filling the confined spaces between the core and the tooth surfaces of the mold, the abrasive particles are as closely packed as possible and an abrasive coating of uniform composition is obtained. Thus, as the material of the hone teeth wears away during the finishing of a multiplicity of gears, the material remains always in its effective honing condition with as many as possible abrasive particles always exposed in the operating surfaces thereof. Moreover, the abrasive surface is a strong hard surface and the abrasive material is characterized by its ability to finish many thousands of work gears in the honing operation.

The drawing and the foregoing specification constitute a description of the improved method of manufacturing metal bonded abrasive gear hones in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. The method of making a metal bonded hone which comprises the step of forming a coating on the surfaces of the teeth of a metal gear-like body by filling the space between the teeth of the body and a matching mold with a mixture comprising an interim binder selected from the group consisting of polyvinyl alcohol, sodium silicate, or an aqueous suspension of spun silica, and abrasive particles, hardening the interim binder in the mold, removing the gear with the hardened coating from the mold, heating the body to dissipate the binder from the coating in the presence of melted metal to cause the metal to be distributed uniformly through the remaining abrasive particles.

2. The method as defined in claim 1 in which the interim binder is polyvinyl alcohol.

3. The method as defined in claim 2 in which the metal is provided in the form of a powder distributed throughout the mixture of abrasive particles and the interim binder, and in which after removal from the mold the body with its coated teeth is heated to melt the metal powder dispersed through the mixture.

4. The method as defined in claim 3 which comprises providing the metal in a step which comprises providing a continuous metal filament at the top edges of the teeth, and in which the metal of the filament is melted and flows into the mixture of the coating as a result of the application of heat which also dissipates the interim binder.

5. The method of making a metal bonded abrasive tool which comprises: forming a mold having a surface conforming exactly to the required form of the tool, positioning a metal body in juxtaposition to said mold to leave a relatively thin continuous space therebetween, solidly packing the said space with irregularly shaped abrasive particles and thoroughly wetting the mass of particles with a fluid interim binder which in solution wets the particles and when dried or set retains the particles in a self-supporting state conforming to the shape of the mold after removal from the mold, but which may be substantially completely eliminated by heating to a temperature below the melting point of a matrix material, causing the binder to harden while retaining the mass of particles in the space between the body and the mold, separating the body with the abrasive particles and hardened binder adhered thereto from the mold, applying a metal matrix material selected from the group consisting of copper, copper-tin alloy or nickel to the body adjacent the adhered particles, and heating the assembly to a temperature sufficient first to eliminate the binder and thereafter to melt the matrix material and to cause it to flow into the voids between abrasive particles left by the eliminated binder to provide a permanent metal bond between contiguous particles and between particles and the metal body.

6. The method of claim 5 which comprises heating the assembly as aforesaid in a hydrogen atmosphere.

7. The method of claim 5 in which said body is generally of circular cross-section and said mold is generally annular.

8. The method of claim 5 in which said body is generally of circular cross-section and said mold is in the form of an internal gear.

9. The method of claim 5 in which said body is in the form of an external gear and the mold is in the form of an internal gear shaped to define a space between the flanks of the teeth of the body and mold.

10. The method of making a metal bonded abrasive gear hone which comprises: forming a mold having a gear tooth mold surface, positioning a metal body in concentric relation to the mold to provide spaces between the tooth flanks of the mold and the body, completely filling the spaces with abrasive particles leaving voids therein as determined by the size and irregular shapes of the particles, thereafter thoroughly wetting the mass of said particles with a fluid interim binder selected from the group consisting of a solution of polyvinyl alcohol or sodium silicate which in solution wets the particles and when dried or set retains the particiles in a self-supporting state conforming to the shape of the mold after removal from the mold, but which may be substantially completely eliminated by heating to a temperature below the melting point of a matrix material, baking the assembly to set the binder, separating the body with the coating of baked binder and abrasive adhered to its teeth from the mold, applying a metal matrix material selected from the group consisting of copper, copper-tin alloy or nickel to the coated body in position to flow into the coating to replace the binder, and heating the assembly at a temperature and for a time sufficient first to eliminate the binder and thereafter to melt the matrix material and to cause it to flow into the voids in the coating.

11. The method of making a hone as defined in claim 10 which comprises the step of heating the assembly in a hydrogen atmosphere.

12. The method as defined in claim 10 in which the particles are limited to a small number of distinctly different particle sizes.

13. The method as defined in claim 10 which comprises the step of forcing the fluid binder into the mass of particles by differential air pressure.

14. The method as defined in claim 13 which comprises forming the fluid binder into the mass of particles until substantially all voids therein are completely filled.

15. The method as defined in claim 5 in which the binder is an organic material and which includes the step of eliminating the binder by the application of heat during the heating of the assembly to melt the matrix material.

16. The method as defined in claim 15 in which the binder is a solution of polyvinyl alcohol.

17. The method as defined in claim 10 in which the body has teeth of reduced chordal thickness relative to the teeth of the mold to define spaces of substantially uniform thickness therebetween.

18. The method as defined in claim 10 in which the abrasive particles are tungsten carbide.

19. The method as defined in claim 10 in which the metal matrix material is a copper alloy.

20. The method as defined in claim 10 in which the metal matrix material is a copper-tin alloy.

21. The method as defined in claim 10 in which the matrix material is nickel.

22. The method of making a metal bonded abrasive gear hone which comprises: forming a mold having a gear tooth mold surface, positioning a metal body in concentric relation to the mold to provide spaces between the tooth flanks of the mold and the body, completely filling the spaces with abrasive particles leaving voids therein as determined by the size and irregular shape of the particles, thereafter thoroughly wetting the mass of said particles with a fluid interim binder which in solution wets the particles and when dried or set retains the particles in a self-supporting state conforming to the shape of the mold after removal from the mold, but which may be substantially completely eliminated by heating to a temperature below the melting point of a matrix material, baking the assembly to set the binder, separating the body with the coating of baked binder and abrasive adhered to its teeth from the mold, supporting the body with its axis vertical from its central portion with its toothed periphery free and unsuppored, applying a metal matrix material selected from the group consisting of copper, copper-tin alloy or nickel at the top of the body continuously around its periphery just inwardly from the roots of the teeth, and heating the assembly at a temperature and for a time sufficient first to eliminate the binder and thereafter to melt the matrix material and to cause it to flow into the voids in the coating.

23. The method of making a metal bonded abrasive gear hone which comprises: forming a mold having a gear tooth mold surface, positioning a metal body in concentric relation to the mold to provide spaces between the tooth flanks of the mold and the body, completely filling the spaces with abrasive particles leaving voids therein as determined by the size and irregular shapes of the particles, thereafter thoroughly wetting the mass of said particles with a fluid interim binder which in solution wets the particles and when dried or set retains the particles in a self-supporting state conforming to the shape of the mold after removal from the mold, but which may be substantially completely eliminated by heating to a temperature below the melting point of a matrix material, baking the assembly to set the binder, separating the body with the coating of baked binder and abrasive adhered to its teeth from the mold, supporting the body with its axis vertical from its central portion with its toothed periphery free and unsupported, applying a metal matrix material selected from the group consisting of copper, copper-tin alloy or nickel at the top of the body continuously around its periphery just inwardly from the roots of the teeth, and heating the assembly at a temperature and for a time sufficient to eliminate the binder from the voids between abrasive particles and to melt the matrix material and to cause it to flow into and fill the voids in the coating created by the elimination of the binder.

24. The method of making a metal bonded abrasive gear hone which comprises: forming a mold having a gear tooth mold surface, positioning a metal body having a similar gear tooth surface in concentric relation to the mold, the teeth of said body being of reduced chordal thickness to provide spaces between the tooth flanks of the mold and the body, completely filling the spaces with abrasive particles leaving voids therein as determined by the size and irregular shapes of the particles, thereafter thoroughly wetting the mass of said particles with a fluid interim binder which in solution wets the particles and when dried or set retains the particles in a self-supporting state conforming to the shape of the mold after removal from the mold, but which may be substantially completely eliminated by heating to a temperature below the melting point of a matrix material, baking the assembly to set the binder, separating the body with the coating of baked binder and abrasive adhered to its teeth from the mold, applying a metal matrix material selected from the group consisting of copper, copper-tin alloy or nickel to the coated body in position to flow into the coating to replace the binder, and heating the assembly at a temperature and for a time sufficient to eliminate the binder from the voids between abrasive particles and to melt the matrix material and to cause it to flow into and fill the voids in the coating created by the elimination of the binder.

25. The method of making a hone as defined in claim 24 which comprises heating the assembly in a hydrogen atmosphere.

26. The method of making a metal bonded hone which comprises the step of positioning a metal gear-like body within a matching mold to define a continuous space between the teeth of the body and mold, filling the space with a mixture of metal particles and abrasive particles, said metal particles being formed from a metallic material selected from the group consisting of copper, nickel and

alloys thereof, thereafter saturating the mixture with an interim binder selected from the group consisting of polyvinyl alcohol, sodium silicate, or an aqueous suspension of spun silica, hardening the interim binder in the mold, removing the body with the hardened coating from the mold and heating the body to a temperature sufficient to melt the metal particles and to substantially dissipate the binder to cause the metal to be distributed uniformly through the abrasive particles.

27. The method as defined in claim 26 which comprises producing the mixture of metal particles and abrasive particles by initially wetting a mixture of metal particles and abrasive particles with the interim binder selected from the group consisting of polyvinyl alcohol, sodium silicate, or an aqueous suspension of spun silica, heating the mixture to form a dry solid material, and breaking up the solid into a multiplicity of particles at least some of which comprise both metal and abrasive.

References Cited

UNITED STATES PATENTS

2,042,635	6/1936	Schellens	51—309
2,334,049	11/1943	Van Der Pyl	51—293
2,363,272	11/1944	Taeyaerts	51—309
2,980,966	4/1961	Praeg	51—298
3,183,633	5/1965	Decker	51—298
3,212,869	10/1965	Decker	51—298
3,248,189	4/1966	Harris	51—295

DONALD J. ARNOLD, Primary Examiner

U.S. Cl. X.R.

51—295, 309