March 26, 1968 G. KOECH 3,375,181

METHOD OF FORMING AN ABRASIVE SURFACE INCLUDING GRINDING AND CHEMICALLY DRESSING

Filed April 21, 1964

FIG. 1

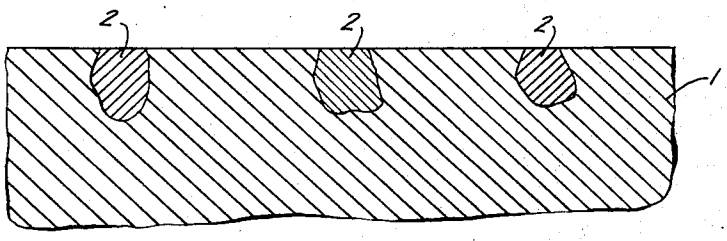


FIG. 3

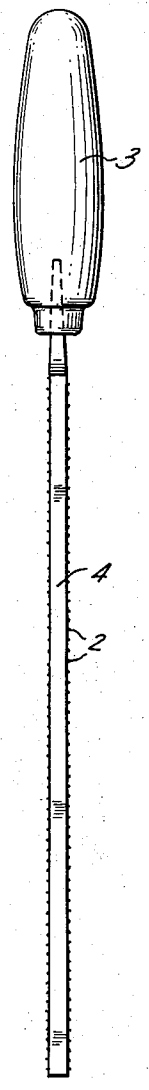
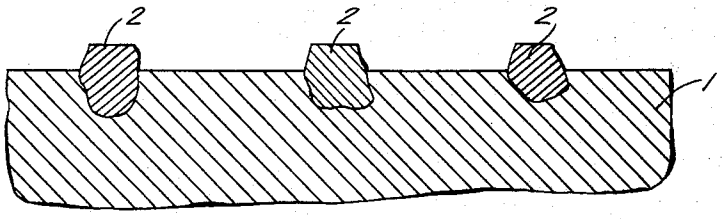


FIG. 2



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METHOD OF FORMING AN ABRASIVE SURFACE INCLUDING GRINDING AND CHEMICALLY DRESSING

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Continuation-in-part of application Ser. No. 44,353, July 21, 1960. This application Apr. 21, 1964, Ser. No. 369,048
Claims priority, application Germany, July 2, 1956, K 29,247
9 Claims. (Cl. 204—143)

The present application is a continuation-in-part of my co-pending application Serial No. 44,353, filed July 21, 1960, now abandoned and entitled "Method for Producing Coarse Rough Operating Surface Portion on Metal Bodies."

The present invention relates to a method for producing coarse, rough operating surface portions on metal bodies, such as tools, friction wheels, belt pulleys, clutch discs and the like, having at least a surface zone or operating surface portion of heterogeneous microcrystalline structure including a minor proportion of the surface zone consisting of relatively very hard crystalline particles surrounded by a major proportion of the surface zone consisting of a less hard component.

It is an object of the present invention to provide a simple and economical method of forming on metal bodies operating surface portions of the desired roughness.

Other objects and advantages of the present invention will become apparent from a further reading of the description and of the appended claims.

With the above and other objects in view, the present invention contemplates a method of producing coarse, rough operating surface portions on metal bodies, such as tools, friction wheels, belt pulleys, clutch discs and the like, having at least at said operating surface portion a surface zone of heterogeneous micro-crystalline structure including a softer main component forming the major proportion of the surface portion, and having distributed through and embedded in the softer main component, a plurality of harder crystalline particles forming the minor proportion of the surface portion, comprising the steps of shaping e.g. by cutting or grinding the operating surface portion, to its desired configuration, and selectively removing the upper layer of the softer main component only, so as to form a surface the major proportion of which consists of the softer main component and the minor proportion of which consists of the harder microcrystalline particles sharpened by said grinding and projecting outwardly from the softer main component to the exact operating surface and forming only a minor fraction of the operating surface portion, whereby due to the outwardly projecting harder particles a rough operating surface portion is formed.

It is essential according to the present invention that the surface portion of the metal body which is to be treated is of heterogeneous composition namely such that the major part of the surface portion consists of a relatively soft material and that harder particles or crystals are embedded therein.

The uppermost layer of the major part of the surface portion, i.e., the softer material, is then selectively removed by chemical or electrolytic action so that the tips of the embedded harder particles which are less susceptible to chemical or electrolytic attack will become exposed and will give to the surface portion the desired degree of roughness.

According to the present invention, it is important that the softer material which is partially removed during the process as described above will form the major portion

of the surface of the surface area of the projecting hard particles of the treated surface will constitute only a minor portion of the total treated surface area.

It is thus possible to produce in an economical and simple manner surfaces which will have exactly the desired configuration and which will possess the desired degree of surface roughness. Removal of the softer portion of the surface area by chemical or electrochemical means can be carried out on surfaces of any desired configuration while, in contrast thereto, imparting roughness by mechanical means becomes difficult on surfaces of irregular or curved shape. The surface structure obtained according to the present invention is excellently suitable for machining tools such as files, broaches and the like.

Broadly, the rough, coarse surface portions are produced on metal bodies which have at least in the operating surface portion a surface zone of heterogeneous crystalline or microcrystalline structure which includes a less hard main component forming the major part of the surface portion and a considerably harder minor portion consisting of particles preferably chemically bonded to the main component. The surface portion of the metal body may be machined, e.g. by grinding, to its desired geometrical shape and thereafter the uppermost layer of the less hard main component is removed by chemical or electrochemical etching. Thereby it will be accomplished that the upper portions of the very hard particles will then project outwardly from the less hard main part of the surface and these projecting very hard generally microcrystalloid surface particles will give to the operating surface portion the desired degree of roughness. It may be noted again that the outwardly projecting harder particles constitute only a minor fraction of the total surface area.

The present method may be applied to producing a great variety of metal bodies shaped to a high degree of accuracy irrespective of the specific geometrical shape involved, such as spherical cups of all sizes, roller bodies, nozzle bores of smaller diameter, spherical bearing surfaces and the like. Preferably, the metal bodies are finished or finally machined or smoothed with tools produced according to the present invention and thereafter the softer component of the surface portion is removed chemically or preferably electrolytically.

This method may also be used for producing on metal parts or workpieces any desired coarse or rough surface portion having a microcrystalline structure which is suitable for positive engagement with a surface portion of another metal body for the purpose of increasing the friction coefficient, while at the same time maintaining the greatest geometrical accuracy. This is important, for instance in the case of clamping members, clamping mandrels, friction wheels and the like. It is common to all applications of the method that hard, usually microcrystalline particles of the desired size or shape are located in the surface zone of the metal body occupying only a minor fraction thereof and projecting outwardly therefrom surrounded by the less hard main component of the surface zone the uppermost layer of which has been removed.

Such surface zones with hard and sharp particles projecting outwardly therefrom may be obtained by chemical or electrolytic dissolution of the outermost portion of the main component of the surface which is softer, under conditions under which the harder particles will not be attacked.

Thus, for instance, hard carbides will remain and project outwardly while the softer metal around the same will be removed.

The very hard particles in the heterogeneous surface portion can be produced for example by diffusing car-

bide-forming agents into the surface portion, for instance by the well known process of cementing.

By diffusing carbide forming agents into the surface of the metal body, for instance in a manner similar to the cementing process, and subsequent removal of the noncarbide surface layer, projecting hard carbide cones will be obtained. The cementing process or the like must be carried out in such a manner that only a minor portion of the surface will be transformed into hard particles such as carbides.

Thus, for instance the main component of the surface portion may be a metal of a certain hardness such as iron, nickel, chromium, tungsten, molybdenum, boron or cobalt which contains chemically bonded microcrystals of greater hardness such as the carbides or nitrides of iron, chromium, vanadium, tungsten, titanium or boron, as a heterogeneous component which will not be attacked during the subsequent electrolytic removal of the surface layer of the main component.

The methods for producing such heterogeneous microstructures are well known in the art. They include the century old method of producing cemented steel by contacting in a cementation furnace a carbon-poor iron with charcoal powder and increasing the heating to a temperature of about 1000° C. which is maintained for a certain period of time.

Thereby, a portion of the iron will be converted into iron carbide (Fe_3C) which then will constitute the harder minor fraction of the surface portion.

Another manner in which a heterogeneous surface portion of a metal body can be produced is the sintering together of a variety of metal powders of different hardness and different susceptibility to chemical or electrolytic attack whereby the softer metal will be such as to be dissolved by such chemical or electrolytic attack while the harder metal distributed therethrough and forming a minor part of the total surface portion will remain unaffected and thus will project outwardly after the uppermost surface layer of the softer portion has been removed. A plurality of sintered layers produced in this manner may then be fused together to form a body or blank of the desired configuration.

Preferably, the workpiece or surface portion is subjected to smoothing prior to removal of the softer component so that the desired accurate shape will be maintained by the outwardly projecting harder particles.

Thus, the invention utilizes the fact that the components of greater hardness, particularly the above-mentioned carbides do not dissolve at all or only to a very low degree during the treatment with chemical solutions or by electrolytic treatment which will dissolve the less hard pure iron (ferrite) at a high rate.

The reason for this selective dissolution is found in the chemical or electrochemical potentials of the specific materials. These must be so chosen that the softer main component will be dissolved while under the given conditions the harder particles are not attacked.

If the metal body consists for instance of a heterogeneous mixture of two chemical components, then the nobler component will not be corroded by the electrolyte before the less noble component which ranges higher in the potential table has been completely dissolved. In the case of steel which consists at least of iron and cementite, the cementite (Fe_3C) is nobler than the iron. By putting a piece of steel, for example a piece of cemented steel having a smooth surface into hydrochloric acid, practically only the ferrite (Fe) will be dissolved but not the cementite (Fe_3C). The microcrystals of the cementite are not corroded and will protrude after completion of treatment from the remaining ferrite surface. In this manner, for instance, a grinding tool may be produced and the protruding microcrystals of cementite are suitable for grinding other bodies.

The method according to the present invention is not limited to iron and cementite but may also be used with different metals such as chromium. Chromium has a potential of plus 1.30. It forms together with carbon a very hard component, namely chromium carbide which is nobler than chromium and thus will not be attacked under conditions in which the chromium will be dissolved.

Contrary to iron, chromium is not soluble in hydrochloric acid since its potential is above the potential of hydrogen. However, it is possible to dissolve the chromium without attacking the chromium carbide by applying a voltage to the chromium which is higher than the natural potential-difference. Thus, by applying a voltage of 1.36 volts against the chromium in an electrolytic cell, the chromium will be dissolved but the chromium carbide will remain intact.

In the same manner, other elements and their embedded microcrystals, particularly the carbides, nitrides, silicates, etc. may be treated, in metal bodies having as main component titanium, vanadium, molybdenum, boron, etc.

Basically, the main, component, i.e., the softer component of the metal body or metal surface portion may be any metal in which is incorporated a minor proportion of harder crystalloids or the like. However, it is generally desirable that the hardness of the main component, i.e., of the softer component, is at least equal to the hardness of pure iron.

The metal body or metal surface portion thus should consist of a heterogeneous microstructure, i.e., chemically bonded microcrystals embedded in the main component and the hardness of the microcrystals is to be greater than that of the material which is to be treated with a tool formed according to the present invention.

While the present description refers primarily to iron and iron carbide, it is of course equally possible to use, for instance, iron and tungsten, or chromium and chromium carbide. The electrochemical potential of the metal of the softer main component must not be as high as that of the embedded microcrystals of the hard material. This condition is met for instance by the combination of iron and cementite (Fe_3C) and in the case of all hard metals, such as tungsten, the carbides and nitrites are nobler than the metallic main component.

The depth to which the softer main component is to be dissolved or the height to which the harder particles are to project outwardly depends on the purpose of the tool to be produced and on the size of the harder microstructures or crystals.

By suitably selecting the chemical solution, the electrolyte, the electric current and the length of the time of treatment, the less hard components of the structure may be removed to a greater or lesser depth, but so that a strong bond between the still partially embedded hard particles and the softer main component is maintained while the points of the very hard particles such as nitrides or carbides will project outwardly a sufficient distance from the remaining surface of the softer main component.

Before removing the uppermost layer of the softer main component, the metal body or surface portion preferably is shaped to its desired dimensionally true geometrical configuration. In this manner it is achieved that the desired outer dimensions will then be represented by the tips of the projecting harder particles. This outermost surface consists then only of the spaced tips of the harder components of the heterogeneous metal surface portion and consequently will possess a very high resistance to wear. Furthermore, the cleaning or sharpening of a tool produced in the above described manner by means of the electrolytic process can be repeated several times. The coarse, sharp-edged surface produced by the present method can be used for tools and metal bodies of all kinds as well as for rollers and the like, since a very high resistance to pressure and bending can be obtained in addition to the high resistance to wear.

In sintered bodies, such as cemented metal carbides,

hardest carbides or carbide forming agents may advantageously be pressed and sintered with less hard or non-hardening metal powder in any desired grain size or mixture provided that the harder constituents will represent only a minor fraction of the total surface area, and in this manner, in accordance with the present invention, it is possible to produce in a relatively simple manner tools having a rough more or less fine or coarse surface and these tools will at the same time possess good edge-holding properties. It is also possible to produce different kinds of pitted surface structures, shallow cavities and the like by distributing the various types of powder in laminae or patterns, sintering, and thereafter electrolytically dissolving the outer most portion of the softer metal of the sintered body.

Due to the high resistance to pressure and the long service life of tools produced according to the present invention, machining by means of such surface contact tools may be carried out with advantage, as for example honing which up to now was difficult with respect to stepped bores or blind holes. In this connection, the favorable heat conducting properties of the metallic body of the tool are of special advantage since they reduce the cutting temperature and the adverse effects such as distortion of the tool, dimensional inaccuracy, etc.

For the purpose of removing the fine chips of metal particles which are produced with scraping tools such as a tool produced according to the present invention, fine flutes or grooves are desirable which may be arranged in any suitable manner, for example, at the periphery of the metal removing surfaces. Various methods may be employed for producing these grooves or shallow recesses, such as hard and soft components arranged in alternate laminae prior to pressing and sintering to form the metal body, or such grooves may be formed by material removing processes, such as electrolytic removal with locally increased removal of material along the lines of contact of two different bodies such as, for example, in the case of painted surface portions.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is a schematic cross-sectional view of a machined portion of a metal body consisting of a softer main component and having distributed therethrough harder microcrystalline particles, prior to chemical or electrolytic treatment according to the present invention;

FIG. 2 is a schematic fragmentary view of the metal body of FIG. 1 after chemical or electrolytic treatment according to the present invention; and

FIG. 3 schematically illustrates a file formed in accordance with the present invention.

Referring now to the drawing, it will be seen that the metal body of FIGS. 1 and 2 comprises a softer component **1** consisting for instance of iron and having embedded in the surface region thereof harder particles such as iron carbide **2**, said surface and particles being shaped by grinding.

As shown in FIG. 2 after removal of the uppermost surface layer of the softer component the ground and thereby sharpened iron carbide particles project outwardly and it will also be seen that the outwardly projecting carbide particles form only a minor fraction of the total surface area.

FIG. 3 shows a file comprising a handle **3** and a working portion **4** on which are indicated in an exaggerated manner the outwardly producing harder carbide particles **2**.

The following example is given as illustrative only of the present invention without, however, limiting the invention to the specific details of the example.

Two samples of fast working tool steel and having the following compositions, were treated in accordance with the present invention as will be described below.

	Sample I	Sample II
Carbon	0.8	0.75
Silicon	0.25	0.25
Manganese	0.3	0.3
Chromium	4.5	4.3
Molybdenum	0.8	0
Cobalt	5.0	0
Vanadium	1.7	1.1
Tungsten	18.0	18.5
Vickers hardness HV	831	841
Rc (approx.)	64.5	65

The roughness of the steel pieces was about 2 microns. After degreasing and grinding the steel pieces, the same were successively subjected to electrolysis in the following two solutions:

Solution A

206 cm.^{3} hyperchloric acid ($HClO_4$), density 1.74
764 cm.^{3} acetic acid anhydride

$(CH_3—CO—O—CO—CH_3)$

300 cm.^{3} H_2O

Solution B

80% by weight phosphoric acid, density 1.84
20% by weight sulfuric acid, density 1.7

The solutions were maintained at about 25° C. and a direct current of 50 volts between cathode and anode was passed through the solution, the steel piece serving as anode. The cathode was formed by a helical cooling pipe, and a current-density of about 4.5 amperes per 100 cm.^{2} was maintained. The metal bodies were uniformly moved in the electrolyte. After treatment for six minutes in Solution A and for ten minutes in Solution B a sufficient roughness of the surface portions of the steel pieces which were thus exposed to electrolysis was attained so that by applying the thus treated steel piece to a hardened steel ball a grinding effect was achieved.

The degree of roughness which can be achieved depends on the size of the particles which are not affected by the electrolytic dissolution of the softer main component, such as carbides, nitrides, harder metals or diamonds. The softer main component should be dissolved only to such depth that the hard particles still remain firmly anchored in the remaining portion of the softer material. Thus, when larger hard particles are embedded in the softer main component a greater degree of roughness can be obtained.

Preferably, the harder particles will form between about 10% and 40% of the planar surface area and the softer main component between 90% and 60%. Depending on the degree of roughness desired, the harder particles which are embedded in the softer main component preferably will have a maximum dimension of between about 5 microns and two millimeters.

The treating solution which is used for removing the surface layer of the softer main component may be such as to effect only a chemical dissolution, or may be used as electrolyte as described in the example. The degree of roughness obtained will depend on the composition of the solution, the length of treatment, the composition of the softer main component and the current applied. For treating steel bodies, for instance, hydrochloric acid, sulfuric acid, titanium tetrachloride, and oxalic acid may be used. It is also possible to treat the metal bodies in a corrosive gas atmosphere which will selectively attack only the softer main component.

If it is desired to diminish the portion of the hard particles in the surface of a tool according to the invention, the portion of the metals forming hard carbides during cementing of the alloy, such as chromium, silicon, wolfram vanadium or the like, may be diminished. Otherwise the temperature during cementing may be increased and the duration of cementing may be diminished, so as to get a minor amount of hard carbides.

For producing tools, such as microfiles, the tool may be built by pressing and sintering together alternating hard and softer plies of sintered metal, the harder or both kinds of plies containing hard micro-crystalline particles embedded in a larger amount of softer binding metal, by which pressing and sintering together the plies are directed vertically to the operating surface, i.e. so that there small edges are forming the operating surface. Then the operating surface portion is ground and thereupon the outer portions of the softer metals of the two kinds of plies are chemically or electrolytically removed. Thereby not only the hard particles are laid bare but also the outer portions of the softer plies including its hard particles are removed more than the outer portions of the harder plies. In this way outer grooves between the harder layers are formed in order to receive filings during operating of the tool.

In order to produce metal tools having diamond particles or the like on the operating surface the particles are galvanized onto a metal body, so that the particles are wholly covered by the metal, e.g. bronze, or the particles and pulverized metal are sintered together in the desired mixture. Then the operating surface of the body is ground and thereupon the outer portion of the binder metal is electrically removed, as described above.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A method of producing a coarse, rough operating surface portion on metal bodies such as tools, friction wheels, belt pulleys, clutch discs and the like having at least at said operating surface portion a surface zone of heterogeneous structure including a metallic main component having distributed therethrough and embedded therein a plurality of sharp-edged metal carbide particles, the latter terminating in a common surface plane outwardly spaced from said main component, comprising the steps of grinding said surface portion of a metal body of substantially the desired shape so as to remove therefrom a layer having a thickness equal to only a fraction of the thickness of said harder particles, thereby also removing the outer portions of said harder particles and forming sharp edges on the remainders of the same which remain anchored in said metallic main component of said surface zone and terminate in the surface plane formed by said grinding; and chemically selectively removing the upper layer of only said main component of the thus ground surface zone, so as to form an operating surface portion consisting of said softer main component and of said sharp-edged metal carbide particles projecting outwardly from said softer main component and terminating in said surface plane of said operating surface portion, whereby due to the sharpening of said harder particles by said grinding and due to the subsequent removal of said upper layer of said main component a rough operating surface portion is formed.

2. A method as defined in claim **1**, wherein said metals of said metallic main component and of said metal carbide particles are identical.

3. A method as defined in claim **2**, wherein said main component consists essentially of ferrite and said particles consist essentially of tungsten carbide.

4. A method as defined in claim **1**, wherein said metal carbide particles form between about 10% and 40% of the surface area of said surface zone, and said main component forms between about 90% and 60% thereof.

5. A method as defined in claim **1**, wherein said metal carbide particles have a maximum dimension of between about 5 microns and 2 millimeters.

6. A method as defined in calim **1**, wherein said chemically selectively removing of the upper layer of said main component is carried out electrolytically.

7. A method as defined in claim **1**, wherein at least said surface zone is formed by producing a coherent metal body of a plurality of thin plies of sinter metal including a small amount of metal carbide particles distributed in a large amount of softer metallic binder material.

8. A method as defined in claim **1**, wherein said metal carbide is selected from the group consisting of the carbides of iron, chromium, vanadium, tungsten, titanium and boron.

9. A method as defined in claim **8**, wherein said material metal carbide is selected from the group consisting of iron carbide and tungsten carbide.

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