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CUTTING ARTICLES AND STOCK THEREFOR AND METHODS OF MAKING THE SAME

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This invention pertains to cutting blades, especially razor blades, and metal stock therefor and to methods of manufacturing the same, and particularly to such articles comprising a high hardness central core and overlying layers of a relatively softer composition.

Very thin gauge cutting articles, such as razor blades, are commonly constructed of high carbon steels containing, for example, 1.2 to 1.4% carbon, balance substantially iron. Such steels do not cut as efficiently or wear as well as many other steels, such as alloy tool steels, but the latter are much too difficult to roll to the required thin gauges. Even the high carbon steels, as aforesaid, generally used for the manufacture of razor blades, are difficult to mechanically reduce to the required extent. Best cutting ability is attainable with materials such as very hard carbides, as the carbides of titanium, tungsten and the like, but such materials are extremely brittle and impossible to produce in sheet form. However, such carbides are frequently utilized in the production of cutting tools by powder metallurgy techniques. For example, such carbides are commonly ground to the form of a fine powder and dispersed in a softer matrix metal, which mixture is then cast into the desired shape. Even such cast articles cannot be mechanically reduced, as by rolling, to thin gauge forms. It is known to the prior art to provide cutting tools as blades and the like with inserts of cast carbides, which are then ground to a relatively fine edge. Such cast materials, however, in view of their relatively high content of the extremely carbide particles are susceptible to easy chipping and breakage.

Prior art attempts to utilize the beneficial effects of hard carbides in the production of cutting tools include mixing preground carbide powders with a softer metal matrix, such as a low melting point, ductile metal, for example, copper, nickel, cobalt, tin, lead, zinc, antimony or bismuth, pressing the mixture by powder metallurgy techniques to the form of a billet, sawing blanks from the billet and grinding the blanks to the desired cutting edge, and then affixing the ground blank, by suitable means such as welding, soldering or brazing, to a suitable backing material. The disadvantages of such procedures and the articles produced thereby are many and varied. For example, the fineness of the edge obtainable by grinding a carbide-containing metal, and the cutting efficiency of the article, are dependent upon the carbide particle size and the uniformity of dispersion thereof in the matrix metal. The particle size obtainable by mechanical size reduction of carbide compositions is limited, as is also the homogeneity of dispersion when such ground powders are mixed with the matrix metal in either molten form or in the form of similarly preground powder. Moreover, the grinding, mixing and compressing steps required in such prior art processes are time consuming and expensive. Additionally, the mechanical steps inherent in assembling a laminated article, such as a cutting blade, from two or more laminations comprising a carbide-containing material are also expensive and are unsuitable for articles of extremely thin overall gauge such as razor blades.

Other attempts have been made by the prior art to produce thin gauge articles, such as razor blades, by methods and means whereby the difficulties inherent in the

reduction of relatively brittle material such as high carbon steel are avoided, or whereby the fragility of the final product, due to its inherent brittleness is overcome. For example, nitriding metal stock has been rolled to final gauge, cut to the desired article shape, ground to a cutting edge and the article then case nitrided to produce a very hard, wear resistant cutting edge. However, such articles cannot be reground because such an operation would destroy the hard nitrided case. Cutting articles have also been prepared by nitriding one side only of a blade, and the blade then sharpened by bevel grinding. Such articles are unsatisfactory because the hard, nitrided edge is unsupported on one side and tends to easy chipping in use. Articles such as cutting blades have also been prepared by assemblying laminates of a plurality of layers wherein an inner layer comprised a hard suitable cutting material overlain with relatively softer, more resilient materials.

Such articles are, indeed, more resistant to breakage during use due to their enhanced resilience, but the difficulties in manufacturing such articles are still formidable. Thus, it is still necessary to reduce the central layer of hard cutting material to very thin gauge form. Moreover, such laminated products, if joined by usual techniques such as welding, soldering or brazing, are not suited for production of extremely thin gauge articles such as razor blades. It is also known in the prior art to utilize carbides in ferrous matrices, by electroplating and infiltrating loosely pressed compacts of carbide particles with molten steel. The disadvantages of such processes and the inapplicability thereof to the production of thin gauge articles are self-evident.

Accordingly, it is an object of the invention to provide cutting tools, in the form of thin gauge articles, such as razor blades, which have enhanced cutting ability, wear resistance and resilience, and thereby have increased effective lives.

It is a further object of the invention to provide a thin gauge, cutting blade having superior cutting properties and amenable to repeated regrinding.

It is another object of the invention to provide unitary stock for the manufacturing of cutting blades and having a central core of hard material for forming a cutting edge and juxtaposed to and integrally united with overlying layers of relatively more ductile, tough and workable material.

It is still another object of the invention to provide thin gauge cutting blades, and stock therefor, comprising a multilayered composition having a central layer containing fine particles of homogeneously dispersed carbides.

It is yet another object of the invention to provide methods for producing the articles as aforesaid.

It is a still further object of the invention to provide articles, as cutting blades, and stock therefor comprising a matrix metal of a relatively ductile, workable metal having dispersed homogeneously therethrough fine particles of hard carbides.

It is another object of the invention to provide methods for producing articles such as cutting blades and the like, and stock therefor, wherein the article or stock comprises a metal cold rollable to relatively thin gauges and which contains a homogeneous dispersion of fine particulate carbides.

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The foregoing and other objects of the invention will be more readily apparent by reference to the following description.

As indicated above, the value of hard carbides such as those of tungsten and titanium as cutting materials is appreciated by the prior art, as is also the similar value of other carbides such as those of columbium, tantalum, zirconium, hafnium and vanadium, and, indeed, some of these materials have been incorporated in preground powder form in various metallic matrices and fabricated by various methods into cutting tools. The known advantages of such carbide materials, for incorporation in cutting tools, are utilized, while the aforementioned, important disadvantages accompanying the production and use of such prior art articles are overcome, by the present invention which provides a unitary cutting article having the cutting edge thereof consisting of a dispersion of extremely small carbide particles in a matrix of a relatively tough, workable, ductile metal.

Such articles are provided by the expedient of in situ formation of the dispersed carbides within the matrix metal, in a restricted zone thereof constituting the ultimate cutting portion of the blade.

The cutting ability and efficiency of a tool comprising a matrix metal containing dispersed carbides is a function of the type of carbide, the quantities thereof present and the homogeniety of dispersion thereof within the matrix metal, as well as, quite importantly, upon the size of individual carbide particles. Thus, the cutting ability and the keenness to which the cutting edge of a carbide-containing blade can be sharpened is directly dependent upon the fineness of the carbide particles. A common defect of prior art carbide-containing compositions, drastically limiting their utility in the construction of fine-edged blades, as razor blades, knife blades and the like, has been the difficulty, and, indeed, the impossibility, of reducing the preformed carbide powders to the necessary, extremely small dimensions and of uniformly dispersing the powders throughout the matrix metal, without obtaining undesirably large agglomerations of the fine powder particles. It has also heretofore been difficult or impossible to homogeneously dispose fine carbide particles within a restricted portion of the matrix metal of an article or stock therefor.

Now, however, by application of the principles of the present invention, carbide particles of small size may be incorporated in a desired matrix, in a homogeneously dispersed form, and, moreover, may be restricted to a particular, desired zone of the matrix metal, thereby enabling the production of a unitary article having a cutting zone of carbide-containing metal, juxtaposed to and forming an integral unit with further zones of substantially carbide-free metal. The advantages inherent therein are obvious, as compared to prior art articles and methods requiring prior production of carbide material, grinding of the same, intermixing with matrix metal to form a cutting composition and then fabrication thereof as by welding, brazing, etc., with additional laminations of carbide-free metal.

Illustrative of the invention is the production of cutting tool blades and metal stock therefor wherein the cutting portion thereof comprises titanium carbide. Thus, a laminate is made comprising a central layer of titanium sheet or foil and juxtaposed upper and lower sheets of low carbon steel, e.g., AISI 1010 carbon steel, containing 0.08–0.13 weight percent carbon. This laminate is then hot rolled to bond the several layers together and to reduce the thickness to nearly the desired final gauge. The hot rolled product is then diffusion annealed to form a titanium-iron alloy layer, e.g., about 2 mils in thickness. The annealed article is then carburized, by suitable means, and for a sufficient time and at a sufficient temperature, to substantially increase the carbon content in the steel layers. Thereafter, the carburized article is subjected to a further diffusion annealing step whereby carbon from the steel sheets is diffused into the titanium core to react therewith, forming discontinuous, homogeneously dispersed titanium carbide particles. The article is then subjected to a partial decarburization to remove excess carbon from the steel sheets, for example, to remove therefrom substantially all carbon remaining in the steel over and above that originally present. The decarburization step may be carried out in any suitable manner in accordance with well-known prior art principles. For example, the carburized article may be subjected to the action of wet hydrogen. In view of the relatively slow decomposition of titanium carbide, control of the decarburization process to stop short of complete carbon removal is easily accomplished. The partially decarburized article is then cold rolled to a desired final thickness. Blanks, in the shape of the desired final article, as a cutting blade or the like, are then cut from the rolled stock and an edge, constituting a cutting edge, is ground by any suitable means.

In the case of some articles, particularly those comprising matrices containing the more reactive alloying elements, as chromium, there is some tendency toward surface and immediate sub-surface oxidation during the decarburization step. Therefore, it may be desirable and advantageous, before cold rolling such surface decarburized articles, to subject the same to a vacuum annealing treatment at time, temperature and pressure sufficient to remove surface and trace internal oxidation to a depth of about 1 mil, without, however, deleteriously affecting the laminar distribution of carbon or carbides in the article. Such objects can be accomplished, for example, by utilizing an anneal at a temperature of at least about 1500° but not over about 200° F., at a pressure less than about 50 microns of Hg for a time of at least about five minutes. The length of time of such heat treatment can, of course, be varied depending upon the severity and the depth of internal oxidation of a particular product. Similar treatment with dry hydrogen, for example, maximum moisture content not over about 25 microns partial pressure (e.g. dew point—40 to 60° F.) at atmospheric pressure, can be substituted for vacuum heat treatment if desired.

Exemplary of the aspect of the invention hereinabove described, titanium foils of 5 mil thickness were interposed between (1) sheets of AISI 1015 steel (0.12 to 0.18% carbon, 0.30 to 0.60% manganese, 0.04% phosphorous, 0.050% sulfur, balance substantially iron), and (2) sheets of AISI 304 stainless steel (0.08% carbon, 2.00% manganese, 0.045% phosphorous, 0.03% sulfur, 1.00% silicon, 18 to 20% chromium, 8 to 12% nickel and the balance substantially iron). All of the steel sheets were of 30 mil thickness. In each instance, the above-described laminates were edge welded with AISI 1015 steel and rolled to a thickness of 10 mils. The rolled products were then annealed in vacuum (although any inert atmosphere could be used) for six hours at 1800° F.–2000° F. (or as high as possible without formation of a eutectic liquid at the interface of the matrix metal and titanium) in order to effect diffusion of the titanium interlayer into the juxtaposed steel layers to produce a central zone of iron-titanium alloy. Late in the diffusion process the temperature may be raised above 2000° F., to enhance diffusion rate, especially in the case of thicker articles. This temperature limitation does not apply in the case of the use of carbide formers in the form of high chromium, tungsten, molybdenum or vanadium alloys which do not tend to form such low-temperature eutectic compositions. It is essential, for the purposes of the invention, that the carbide-forming interlayer be thoroughly alloyed with adjacent portions of the matrix metal in order to avoid a sharp interface with the matrix metal, inasmuch as such an interface would tend to cause separation. Such diffusion of the centrally disposed, carbide forming layer should not, however, be carried to an extent as to destroy a discrete carbide-forming center layer. Such precaution in avoiding destruction of the carbide-forming center layer is, of course, unnecessary except in the case of extremely thin articles, as razor blades, since, with the slow diffusion

rates involved, even relatively prolonged heating of thicker articles would not deleteriously affect the central layer. Thereafter, the articles were carburized by heating the same for one hour at 1800° F. in a natural gas atmosphere containing a small percentage of oxygen to deposit a thin film of carbon on the surfaces of the products. The carburized products were then partially decarburized by heating for one hour at 1800° F. in wet hydrogen (70° F. dew point). Examination of the decarburized product showed a central region having a high concentration of titanium carbide particles ranging in size from about 1 to about 50 microns and dispersed in a matrix of the overlying metal.

It will be obvious to one skilled in the art that other strong carbide-forming materials than titanium may be substituted for the core layer of the initial laminate in accordance with the foregoing description. Thus, the core layer may comprise zirconium, columbium, tantalum, hafnium or vanadium. Chromium, tungsten or molybdenum may also be used. Alloys of any of these elements, or combinations thereof, may be used. Any suitable, desired base metal may be utilized in the production of such alloys for use as core layers in the contemplated laminated raw material.

Further, a wide variety of materials are useful as outer layers for the aforementioned laminates. Thus, high carbon steels may be used, in combination with a core layer of any one or more of the aforementioned carbide-forming elements or alloys therein. High carbon steels have the disadvantage of exhibiting considerably higher resistance to rolling to thin gauge form than the lower carbon steels. However, high carbon steels, e.g., AISI 1025, containing 0.22–0.28 percent carbon, are useful in that, by the use of such higher carbon steels, the carburizing step can be omitted and reaction with the carbide-forming core material can be accomplished simply by diffusing carbon thereinto from the outer layers of high carbon steel which is thereby depleted of carbon, resulting in a final product comprising low carbon exterior layers enclosing an inner layer having the thus-formed carbides dispersed therein.

Still other materials are useful as outer layers in the initial laminate, e.g., various stainless steels, other iron-base alloys, or softer metals, as copper, tin, zinc, etc., or alloys thereof.

On occasion, it may be desirable to assemble the initial laminated article in the form of an enclosed, evacuable pack for subsequent treatment and rolling, as aforesaid. In such instances, the readily workable, outer laminations may comprise the pack exterior, enclosing the inner lamination of the stable carbide-forming metal, and sealing may be accomplished by edge welding in accordance with well-known techniques of the prior art. The pack, so constituted, may be evacuated, or may be supplied with an atmosphere of a suitable inert gas, as argon, etc. The purpose of such constructions and procedures is, of course, to avoid oxidation of the stable carbide forming metal of the inner lamination with consequent tendency of the final product to delaminate readily.

Alternatively, the contemplated articles may be produced from a unitary stock. For example, a low carbon iron-base alloy, as, one of the commercial cold-rollable stainless steels, for example, AISI 430 (0.12% C), or a low carbon steel, as AISI 1010, or any other relatively readily rollable, low carbon iron-base alloy. Such alloys which, in accordance with the common knowledge of the prior art, are most readily cold rollable, are preferred as initial starting material. Pursuant to this aspect of the invention, metal stock, as aforesaid, is rolled to penultimate thickness, whereupon it is carburized as aforesaid. Carburization is carried out to any desired extent, but is preferably limited to less than complete saturation of the metal with carbon, to avoid complete embrittlement of the metal, which would make handling thereof extremely difficult. The carburized metal is then subjected to a diffusion annealing treatment for a time and at a temperature sufficient to produce substantial homogeneity of carbon throughout the metal. The increased carbon content, of course, results in a considerably enhanced hardness of the metal, thereby making the same more suitable for cutting applications than the unhardened, low carbon raw material. Moreover, in the case of metals containing carbide-forming elements, as chromium, vanadium, molybdenum, tungsten, etc., interaction thereof with carbon during the aforesaid treatment is also productive of the corresponding metallic carbides which also contribute to the cutting ability of the final product. However, the increased hardness due to higher carbon contents is accompanied by a decrease in ductility and toughness of the metal, which makes rolling and other fabricating steps quite difficult. Indeed, as described above, it is such factors which commonly preclude use of high hardness metals in the manufacturing of thin gauge cutting tools as razor blades and the like.

However, it has now been found possible to utilize such high hardness materials, prepared as above described, by subjecting the same to a surface decarburization step, whereby carbon in the surface layers of the carburized, annealed stock, is reduced to a level conducive to cold rolling, e.g., to a carbon level about that present in the initial, untreated stock. The result, then, is a unitary stock of base metal, having a relatively higher carbon, high hardness, central core, either with or without metallic carbides, as aforesaid, integral with overlying, exterior layers of relatively lower carbon base metal which exhibit properties of higher ductility, toughness and workability than the core layer. Consequently, the surface decarburized metal may then be readily cold rolled to a final desired thickness. The highly workable exterior layers effectively support the higher hardness central core and thereby enable the mechanical reduction thereof to the desired, final thickness without danger of cracking or breaking. The thus-produced stock is then cut, by suitable means, to form blanks of a desired article form.

Illustrative of the aspect of the invention as above described, AISI 430 stainless steel, a ferritic steel comprising 0.12% carbon, 1.00% manganese, 0.040% phosphorous, 0.03% sulphur, 1.00% silicon, 14 to 18% chromium, balance substantially iron, was rolled to a thickness of 10 mils and the rolled material was then carburized in an atmosphere of natural gas containing a small percentage of oxygen sufficient to deposit a thin film of carbon on the steel surface. The carburization step was carried out at 1800° F. for a period of two hours. The carburized article was thereafter diffusion annealed in a vacuum at a temperature of 1800° F. for a period of three hours whereupon the carbon content of the article was substantially uniformly diffused therethrough. The carburized and annealed article was then subjected to a partial decarburization in wet hydrogen (70° F. dew point), at 1800° F. for one hour. Examination of the decarburized product showed top and bottom layers approximately 3 to 4 mils thick wherein decarburization had reduced the carbon content to essentially that of untreated 430 stainless steel, and a central layer from 2 to 4 mils in thickness of relatively high carbon content, i.e., about one weight percent carbon. The decarburized product was then cold rolled to a final thickness of six mils. It was found, upon examination of sections of the final composite metal stock that the same comprised a central layer or core about 0.0015 inch thick of a transformed austenitic structure having a relatively much higher carbon content than the adjacent, outer layers, each of which measured 0.0023 inch in thickness, although there were no sharply defined boundary layers separating the high carbon interior from the low carbon surface material. The core layer, by reason of its transformed austenitic structure, and because of its higher carbon content, was inherently much harder, and hence more

suitable for cutting and wear resistance, than the lower carbon outer layers.

The invention is not limited to the above-mentioned illustrative articles, but is applicable to a wide variety of products and methods of making the same. Thus, the invention is useable with great advantage in the production of a wide variety of other cutting tools, as machine cutting tools, tool bits, agricultural discs and the like, as well as articles and stock as structural articles, etc., wherein a high hardness, delamination-resistance core is useful or required.

Manifestly, still further modifications and additions may be made to the above-mentioned descriptive and illustrative matter without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of producing flat metal articles for cutting blades, comprising forming a laminated stock consisting of an inner layer comprising a strong carbide-forming metal and outer layers comprising a mechanically workable, matrix metal having substantial solid solubility for carbon and forming therewith carbides relatively less stable than those formed by the strong carbide-forming metal of the inner layer, heating the laminated stock to diffuse the carbide-forming metal of the inner layer into adjacent portions of the outer layers, carburizing the stock, annealing the carburized stock to effect diffusion of carbon therethrough and to form a centrally disposed, discrete, interior layer of matrix metal containing a substantially homogeneous dispersion of stable carbides, partially decarburizing the stock to substantially eliminate the relatively more unstable carbides and dissolved carbon and to restore the outer layers of matrix metal to a mechanically workable condition, and rolling the stock to a desired, final article thickness.

2. A method of making flat-rolled mill articles comprising a matrix of a relatively ductile, workable metal and a continuous, centrally disposed, inner layer containing dispersed carbide particles adapted to form a cutting edge, comprising forming a laminated stock consisting of an inner lamination of a relatively active metal capable of forming stable carbides and juxtaposed outer laminations of a rollable matrix metal capable of forming carbides relatively less stable than those of said reactive metal, diffusion alloying the reactive metal and adjacent portions of the matrix metal to form an inner alloy layer of matrix metal and reactive metal, carburizing the stock to form reactive metal carbides in the inner layer, decarburizing the outer laminations of the stock, and rolling the stock to a desired final article thickness.

3. A method of producing flat-rolled metal articles comprising a hard, wear-resistant, inner layer capable of forming a cutting edge and outer layers of a relatively ductile, workable metal, comprising interposing between outer layers of the workable metal a layer comprising a stable carbide-forming metal, diffusing carbon through the outer layers to react with the stable carbide-forming metal to form a dispersion of stable carbides in a matrix of the workable metal, decarburizing the outer layers of workable metal, and working the resulting product to a desired final article form.

4. A method for making flat-rolled mill stock comprising forming a pack consisting of an inner lamination of a strong carbide-forming metal and juxtaposed outer laminations of a rollable metal forming carbides relatively less stable than those of the strong carbide-forming metal, excluding air from the pack, diffusing the inner lamination into adjacent portions of the outer laminations, carburizing the pack to form an inner layer containing substantially uniformly dispersed stable carbides, partially decarburizing the pack, and rolling the pack to a desired final thickness.

5. A method of making a cutting tool having a relatively hard, wear-resistant inner layer constituting a cutting edge and relatively softer, ductile, outer layers, comprising interposing between stock laminations of the softer, more ductile metal, a lamination comprising a stable carbide-forming metal, carburizing the laminated stock to form stable carbides in a zone corresponding to the interposed lamination, decarburizing the outer laminations, rolling the carbide-containing stock to a desired final thickness, forming cutting tool blanks from the rolled stock, and double bevel grinding at least one edge of the blank to expose the inner, carbide-containing layer to form a cutting edge.

6. A method for producing a metal article having a core of high hardness and relatively softer overlying layers comprising: forming a metal composite having a central zone of a strong carbide-forming metal, producing thereover a high-carbon outer zone of metal having a substantially higher carbon content than said strong carbide-forming metal, annealing said composite to diffuse carbon throughout said composite to form within said central zone discontinuous, homogeneously dispersed carbide particles of said carbide-forming metal, and subjecting said composite to a decarburizing treatment to remove at least a portion of the carbon from the outer zone thereof.

7. A method according to claim **6** wherein said high-carbon outer zone is produced by carburizing said composite to increase the carbon content of the metal of said outer zone to a level substantialy higher than the carbon content of the metal of said central zone.

8. A method according to claim **7**, wherein said composite is cold reduced to a final thickness after decarburization.

9. A method according to claim **8**, wherein said composite is deoxidized after decarburization.

10. A method according to claim **9**, wherein said composite is deoxidized by annealing at a temperature between about 1500° F. and 2000° F., at a pressure below about 50 microns Hg, and for a time of at least five minutes, whereby internal oxidation of said composite is removed to a depth of about 1 mil.

11. A method according to claim **6**, wherein portions of said central-zone metal and said outer-zone metal are alloyed along the interfaces thereof.

12. A composite metal article produced in accordance with the method of claim **6**.

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