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TOOL STEEL

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6 Claims. (Cl. 75—22)

This invention relates to steel and more particularly to a tool steel fabricated from powdered materials.

In our copending application, Serial No. 225,844, filed August 20, 1930, and entitled Steel, we have disclosed a process for fabricating steel from a mixture of powdered material, in which the austenitic structure characteristic of steel is obtained in one embodiment thereof by sintering a mixture of powdered iron and powdered ferro-alloys having a high content of combined carbon, the sintering being conducted to the critical range at which the micro-structure becomes austenitic, for a sufficient period of time to effect a uniform diffusion of the combined carbon into the mass. In the aforesaid application it is contemplated that the proportion of high carbon ferro-alloy will be such as to impart the desired carbon content to the steel. The product thus produced is a high quality steel which may be hardened to the same degree and in the same manner as cast steels of similar composition.

The present invention is directed to a similar process, one of the objects being to provide a steel of extreme hardness and resistance to wear.

Another object is to provide a steel of the above nature which exhibits normal ductility.

Another object is to provide a composition composed of a steel matrix having uniformly distributed therethrough particles of extreme hardness.

Another object is to provide such a composition in which the hard particles are mechanically and chemically bonded to the steel matrix.

Other objects and advantages will hereinafter appear.

In accordance with the present invention we produce a steel having carbide particles uniformly distributed therethrough, such as chromium, tungsten, vanadium or molybdenum carbides, or the complex carbides of these materials as found in the ferro-alloys such as chromium-iron carbides, vanadium-iron carbides, molybdenum-iron carbides, tungsten-iron carbides, etc. The composition is produced by mixing a powdered iron carbide, such as the complex iron carbides mentioned above with powdered iron in the proper proportion, pressing the mixture into the desired shape and sintering the pressed part to a temperature within the critical range where the structure is austenitic for a sufficient period to cause a portion of the combined carbon in the iron carbide to diffuse through the iron powder to form a steel. The proportion of iron carbide added to the composition is in excess of that required to form the steel and the remainder of the iron carbide remains as undissolved or partially dissolved iron carbide in a steel matrix. Since the combined carbon is concentrated in the iron carbide particles at the commencement of the sintering, the migration of the iron carbide is towards the portion of the composition of lower concentration, namely, the iron powder. The diffusion of the iron carbide of the individual particles into the more pure iron results in a mechanical interlocking or bonding of the particles and the union of the combined carbon with the iron results in a chemical bonding of the particles. The sintering may be stopped at any point in the diffusion of the combined carbon into the iron so as to produce a steel matrix of any desired carbon content or it may be continued to saturation of the iron after which no further diffusion will occur. The particles of iron carbide in excess of that utilized in producing the austenitic microstructure of the steel remain as discrete carbide particles intimately bonded both chemically and mechanically to the steel matrix.

The steel matrix may be hardened in the manner of any carbon steel of similar composition and the resulting product is an extremely hard matrix containing still harder carbide particles.

The amount of excess carbide may be varied in order to obtain any desired hardness and wear resistance of the part. For example, 15% of chromium-iron carbide, having a composition of 65% chromium, 8% combined carbon, and the remainder iron, may be intimately mixed with 85% of iron powder. A pressed mass of this composition may be heated to the critical range and maintained at that temperature for a sufficient time to effect such diffusion of the carbide as to give a steel matrix of approximately 0.8% carbon, that is, until substantially 10% of the combined carbon is utilized to form the austenitic structure. The remaining 5% of chromium iron carbide then remains as discrete particles held in the steel matrix. By increasing or decreasing the percentage of chromium-iron carbide or employing a chromium-iron carbide of either greater or less combined carbon content, the amount of undissolved chromium-iron carbide in the composition may be increased or decreased.

If desired, various mixtures of iron carbides may be added to the iron powder, as for instance, a mixture of powdered chromium-iron carbide and tungsten-iron carbide may be added to iron powder.

In place of using substantially pure iron powder we may use iron powder which has been

carburized either prior to or after pulverization. Such carburizing may be effected by heating powdered sponge iron in a suitable container of iron, alundum, etc., in a gas carburizing furnace, such as a rotary gas carburizing furnace or a reverberatory furnace of the type used in roasting ores. Agitation of the powder during carburization decreases the time required to effect the desired result. We prefer to employ a soft iron which is comparatively free of impurities. The length of heating depends mainly upon the degree of carburization desired, the nature and rate of flow of the carburizing gas employed, the agitation of the material and the particle size of the powder. The carburizing process may be substantially the same as that employed in the carburizing of solid iron or steel and may be conducted in such gases as propane, natural gas, carbon-monoxide, or other well known commercial carburizing fluids by which carbon is introduced into iron by the gaseous method.

The carburizing of the iron powder results in a case hardening inwardly from the surface thereof which hardness increases with the increase of carbon content. Due to the hard nature of such carburized powder, it is extremely difficult to effect cohesion of the particles during the pressing operation. We have found, however, that this difficulty can be overcome by properly annealing the carburized powder prior to pressing thereof into the desired form. This may be effected by reheating the powder after carburization to the annealing temperature thereof, this temperature depending upon the carbon content of the powder and being of the order of magnitude of from 1500 to 1700° F. The powder is then permitted to cool very slowly.

Annealing may also be effected by a very slow cooling of the powder following the carburization thereof. This annealing results in a softening of the carburized powder whereby it more readily coheres during the subsequent pressing operation. If the carburized powder is diluted with pure iron powder, the cohesion of the particles in further enhanced.

In place of using carburized iron powder, powdered steel may be employed. The steel powder should preferably be annealed prior to compression thereof, as above set forth.

Any desired quantity of metallic carbides, such as tungsten, vanadium, chromium, or molybdenum carbide or complex carbides of these metals with iron, may be added to the carburized iron powder either with or without additional uncarburized iron powder. The carburized iron, during sintering, will produce the desired austenitic structure of steel with the harder carbides distributed therethrough.

The exact composition of the powdered mass may be varied, as desired, as long as there is present therein a sufficient proportion of a metallic carbide to impart the required martensitic structure to the sintered and hardened body with a further quantity of the same or another metallic carbide, in the form of discrete particles, to impart additional hardness and wear-resisting properties to the sintered mass.

For fabrication of an article the powdered material is placed in a suitable container which is filled to a depth of approximately three times the depth of the finished article. The plunger is thereafter forced into the container under the pressure of approximately one hundred thousand pounds per square inch, which pressure compacts the powder to approximately one-third of its original bulk. The exact reduction in volume of the powder, upon compression, is dependent upon the particular mixture employed. After the pressing operation the compressed powders are coherent and may be readily removed from the mold, by means of an ejector of the usual type. The compact may then be sintered at a suitable temperature in an inert atmosphere, such as hydrogen, for a sufficient period to coalesce the constituents into a uniform mass. The sintering temperature should be above the critical range of the particular composition so that the carbide will be dissolved in the austenite, as in the ordinary heat treating process of steels. After sintering the part may be quenched from the sintering temperature, in the accepted manner ordinary to steel treatment.

As an example of the specific process a mixture comprising 5% pure iron, 90% carburized and annealed iron, which contains 1% combined carbon in the iron carbide, and 5% tungsten carbide was pressed at approximately one hundred thousand pounds per square inch and sintered in a non-oxidizing atmosphere at a temperature of 1200 to 1300° C. for a period of two to four hours in a high frequency induction furnace. The resulting metal was subsequently hardened in accordance with the usual hardening practice and oil quenched. The structure was typical of a carbon tool steel matrix in which was incorporated the tungsten-carbide particles. The microconstituents of the matrix were typical of tool steel, as for instance martensite.

It is obvious, of course, that many changes may be made in the method of compacting the powders and uniting powders of different compositions, those shown being by way of illustration only. Therefore, we do not desire to be limited to the specific processes disclosed, but contemplate all variations thereof as coming within the scope of the appended claims.

We claim:

1. The method of making a steel of extreme hardness and resistance to wear comprising producing a mixture of powdered iron containing carbon in the form of a metallic carbide, the metallic carbide being present in a quantity in excess of that required for reaction with the iron powder to produce the desired steel structure, pressing said mixture to render it coherent, heating the mixture to above the critical temperature for a period sufficient to cause union of the iron powder with the desired quantity of carbon and discontinuing said heating before all of said metallic carbide has been so united.

2. The method of making a steel of extreme hardness and resistance to wear comprising producing a mixture of powdered iron and iron carbide, the iron carbide being present in a quantity of from 1 to 5% in excess of that required for reaction with the iron powder to produce the desired steel structure, pressing said mixture to render it coherent, heating the mixture to above the critical temperature for a period sufficient to cause union of the iron powder with the desired quantity of carbon and discontinuing said heating while from 1 to 5% of said iron carbide remains un-united.

3. The method of making a steel of extreme hardness and resistance to wear comprising producing a mixture of powdered iron and chromium-iron carbide, the chromium-iron carbide being present in a quantity of from 1 to 5% in excess of that required for reaction with the iron powder to produce the desired steel structure, pressing

said mixture to render it coherent, heating the mixture to above the critical temperature for a period sufficient to cause union of the iron powder with the desired quantity of carbon and discontinuing said heating while from 1 to 5% of said chromium-iron carbide remains un-united.

4. The method of making a steel of extreme hardness and resistance to wear comprising producing a mixture of approximately 5% powdered iron, 90% powdered carburized iron containing about 1% combined carbon, and 5% powdered tungsten carbide, pressing said mixture to render it coherent, heating the mixture to above the critical temperature for a period sufficient to cause union of the iron powder with the desired quantity of carbon and discontinuing said heating while from 1 to 5% of said tungsten carbide remains un-united.

5. The method of making a steel of extreme hardness and resistance to wear comprising producing a mixture of powdered iron and a powdered carbide of one or more of the metals of the group consisting of tungsten, vanadium, chromium, molybdenum and iron and complex carbides of such metals with iron, the powdered carbide being present in a quantity in excess of that required for reaction with the iron powder to produce the desired steel structure, pressing said mixture to render it coherent, heating the mixture to above the critical temperature for a period sufficient to cause union of the iron powder with the desired quantity of carbon and discontinuing said heating before all of said powdered carbide has been so united.

6. The method of making a steel of extreme hardness and resistance to wear comprising producing a mixture of powdered iron and a powdered carbide of one or more of the metals of the group consisting of tungsten, vanadium, chromium, molybdenum and iron and complex carbides of such metals with iron, the powdered carbide being present in a quantity of from 1 to 5% in excess of that required for reaction with the iron powder to produce the desired steel structure, pressing said mixture to render it coherent, heating the mixture to above the critical temperature for a period sufficient to cause union of the iron powder with the desired quantity of carbon and discontinuing said heating before all of said powdered carbide has been so united.

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