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POWDER METALLURGY OF HIGH-SPEED STEEL

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This invention relates to the production of mechanical and electrical elements, such as tools, of high speed steel by powder metallurgical methods.

High speed steel is difficult to work and it is desirable, therefore, to produce the desired shapes by powder metallurgy, i. e., to form a powder of the high speed steel or which will yield high speed steel and mold it into a coherent mass by compressing it and uniting the particles by sintering.

By forming or shaping the article by powder metallurgical methods the customary casting, forging, machining, etc., are eliminated with great resultant economy in the production of the article.

By high speed steel I mean alloys referred to in the literature as such and generally described as containing about 13–19% tungsten, 3–4% chromium, 0.25% to 2.25% vanadium and 0.5 to 0.8% carbon with optional additions of up to 0.75% molybdenum, 5 to 9% cobalt, and small amounts of other elements such as silicon, manganese, phosphorus and sulfur, the balance being iron.

It is known to be possible to produce tools etc. which are superior to those now commercially available from high speed steel alloy of unusual or abnormal composition. For example tools made of high speed steels containing more than 20% of tungsten or more than 10–15% of molybdenum with correspondingly super normal contents of carbon, chromium, vanadium and cobalt have showed superior cutting efficiency. However tools of such alloys have been made only experimentally because their production by conventional methods of making high speed steel tools involves such difficulties as to render their commercial production unpractical. Such compositions normally require working to break up the precipitated complex carbides. Moreover many of such compositions are not forgeable and it is necessary to cast them directly into their final shape which frequently is complex and renders the casting very difficult.

The present invention is applicable advantageously for the production of tools etc. from high speed steels of both the normal and the unusual compositions above referred to.

In accordance with the present invention a ferrous metal alloy of the desired composition containing alloying metals characteristic of high speed steels but containing for example 1.5 to 3.0% of carbon is prepared and subdivided in the liquid state to a size and shape suitable for further mechanical disintegration in the solid state, e. g., it is subdivided into a cooling fluid such as water to form pellets or shot of varying size, say about 10 mm. diameter or less, and then ground to a powder of suitable fineness for powder metallurgy, say 40 to 60 mesh.

The mechanical disintegration of the liquid-subdivided metal may be facilitated by a heat treatment to render the metal more brittle, e. g., by heating to at least 1800° F. and then quenching in water or oil. It may be advantageous also to heat the quenched liquid-subdivided metal to 1050–1100° F. and allow it to cool normally without quenching.

The subdivided metal is then decarburized by the process disclosed in Reissue Patent No. 21,500 or by using wet hydrogen, i. e., a mixture of hydrogen and steam, as the decarburizing agent. The essentials of the decarburizing process are that the finely divided metal is heated to a temperature, e. g., 1800° F. or higher at which its carbon content will react with the decarburizing agent, e. g., a mixture of CO and CO_2 or a mixture of water vapor and hydrogen but below the melting point of the metal, and is agitated in some manner as by movement through a rotary kiln or furnace to expose all of the particles to contact with the decarburizing gas. The metal may be heated in various ways as described in said patent, the bulk or all of the heat necessary being supplied by the reaction between the decarburizing gases and the carbon content of the metal. Additional heat may be supplied by combustion of a portion of the decarburizing gas, e. g., by introducing oxygen, or additional combustible material such as carbon, hydrocarbons, etc., may be introduced into the furnace for combustion and the liberation of heat. The decarburizing process is so controlled by regulating the temperature and the composition, e. g., the ratio of hydrogen to steam in the decarburizing gas mixture as to avoid excessive oxidation of the metal. For example, the hydrogen and steam may be so proportioned in one part of the furnace as to actively decarburize the metal with some superficial oxidation, i. e., the gas in this part of the furnace is made to contain a relatively high ratio of steam to hydrogen, and the gas mixture is so proportioned in another part of the furnace as to remove the oxide film. That is to say, the metal is passed through the furnace first contacting a gas atmosphere which is quite strongly oxidizing and then contacting a gas atmosphere which is quite strongly reducing so that in the first stage the carbon is burned out with some oxidation of the metal and in the second stage the metal oxide is reduced.

The manipulation of the decarburizing treatment, including control of temperature and gas composition, to attain the desired decarburization of the metal, is within the skill of a metallurgist following the teachings in said patent and need not be discussed further in detail.

The decarburization is conducted to the desired carbon content, say 0.5 to 0.8%, and the resulting metal powder may be used directly or after classification as to size or after further mechanical distintegration or both in the powder metallurgical process. For example, the decarburized powder may be heat treated as described above, i. e., by heating to 1800° F. or higher and quenching in water with or without tempering to 1050 or 1100° F., and then further ground to produce a finer powder.

The powder is formed into objects in the customary manner, e. g., hot pressed in the final desired form directly or hot pressed to approximately the desired shape and then hot forged to final shape or cold pressed with due allowance for dimensional changes and then sintered in a neutral or reducing atmosphere at 2100 to 2600° F. The formed object produced by hot or cold pressing and sintering of the powdered metal is then subjected to treatments which are customary in the finishing of high speed steel articles such as tools, e. g., it may be hot forged from the sintering temperature to finish the shape of the article and/or promote consolidation, heat treated, etc.

The essence of the invention as described above is the production of high speed steel articles by powder metallurgy involving first the preparation of a high speed steel alloy having a carbon content substantially in excess of that desired in the finished article, liquid subdivision of the metal, mechanical disintegration of the liquid-subdivided metal in the solid state, decarburization of the metal in the solid state, shaping of the powder by pressure and sintering.

This basic process is susceptible to modification in a variety of ways, some of which have been described above and some of which are well known in powder metallurgy. In the powder metallurgical treatment of the powder it may be mixed with binders, alloying metals, abrasives, lubricants, materials designed to produce porosity, etc.

High speed steel powder produced as described has been found to be well adapted to powder metallurgical manipulation and objects made therefrom by powder metallurgical methods have been found to be useful as substitutes for high speed steel objects made by conventional procedure.

I claim:

1. Process for the production of high speed steel powder suitable for powder metallurgy which comprises preparing a ferrous metal alloy containing alloying constituents characteristic of high speed steels but having a carbon content substantially in excess of that desired in the high speed steel powder to be produced, mechanically disintegrating said metal alloy in solid state and decarburizing said metal alloy in solid state to the extent required to produce high speed steel of desired carbon content.

2. Process as defined in claim 1 in which the carbon content of the prepared alloy is within the range of from approximately 1.5% to approximately 3.0%.

3. Process as defined in claim 1 in which the carbon content of the prepared alloy is within the range of from approximately 1.5% to approximately 3.0% and in which the material is decarburized to an extent providing a final carbon content within the range of from approximately 0.5% to approximately 0.8%.

4. Process as defined in claim 1 in which the percentages of alloying constituents in the prepared alloy are abnormally high as compared with the percentages of like constituents in high speed steels of normal composition.

5. Process for the production of high speed steel powder suitable for powder metallurgy which comprises preparing a molten mass of ferrous metal alloy containing alloying constituents characteristic of high speed steels but having a carbon content of from approximately 1.5% to approximately 3.0%, subdividing said alloy while in molten state, mechanically disintegrating the subdivided material in solid state and decarburizing the material in solid state to the extent required to produce high speed steel material of desired carbon content.

6. Process according to claim 5 in which the subdivided material in solid state is subjected to heat treatment consisting of heating to at least 1800° F. and quenching in liquid prior to the step of mechanical disintegration.

7. Process according to claim 5 in which abnormally high percentages of alloying constituents as compared with the percentages of like constituents in high speed steels of normal composition are incorporated in the prepared molten mass of alloy and in which the subdivided metal in solid state is subjected to a heat treatment consisting of heating and quenching to enhance the brittleness of the material prior to the step of mechanical disintegration.

8. Process according to claim 5 in which abnormally high percentages of alloying constituents as compared with the percentages of like constituents in high speed steels of normal composition are incorporated in the prepared molten mass of alloy, and in which the decarburizing step is terminated before the carbon content of the material is reduced to a value normal for usual high speed steels.

9. Process of producing a tool or die of high speed steel which comprises preparing a molten mass of ferrous metal alloy containing alloying constituents characteristic of high speed steels but having a carbon content of from approximately 1.5% to approximately 3.0%, subdividing said alloy while in molten state, mechanically disintegrating the subdivided material in solid state, decarburizing the material in solid state to reduce the carbon content thereof to from approxmately 0.5% to approximately 0.8% and forming the desired tool or die to approximately finally desired configuration by subjecting the mechanically disintegrated and decarburized material to powder metallurgy operations involving heat and pressure.

10. Process of producing a tool or die of high speed steel having substantially unforgeable physical properties which comprises preparing a molten mass of ferrous metal alloy containing carbon and alloying constituents characteristic of high speed steels in abnormally high amounts as compared with the amounts characteristic of usual high speed steels, subdividing said alloy while in molten state, subjecting the subdivided material in solid state to heat treatment involving heating and quenching to enhance the brittleness thereof, mechanically disintegrating in solid state the subdivided and heat treated material, decarburizing the mechanically disintegrated material to reduce the carbon content thereof to desired value and thereafter forming the desired tool or die to approximately desired final configuration by powder metallurgy operations involving heat and pressure.

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