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(54) **POWDER-METALLURGICAL STEEL**

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(57) **ABSTRACT**

The invention relates to a method for producing powder-metallurgical steel. Said method consists of the following steps: a steel powder, preferably having a predetermined structure, is produced; the steel powder is mixed with a binding agent to form a plastically deformable raw material; the raw material is initially shaped to form a blank having a predefined spatial form; and the blank is sintered.

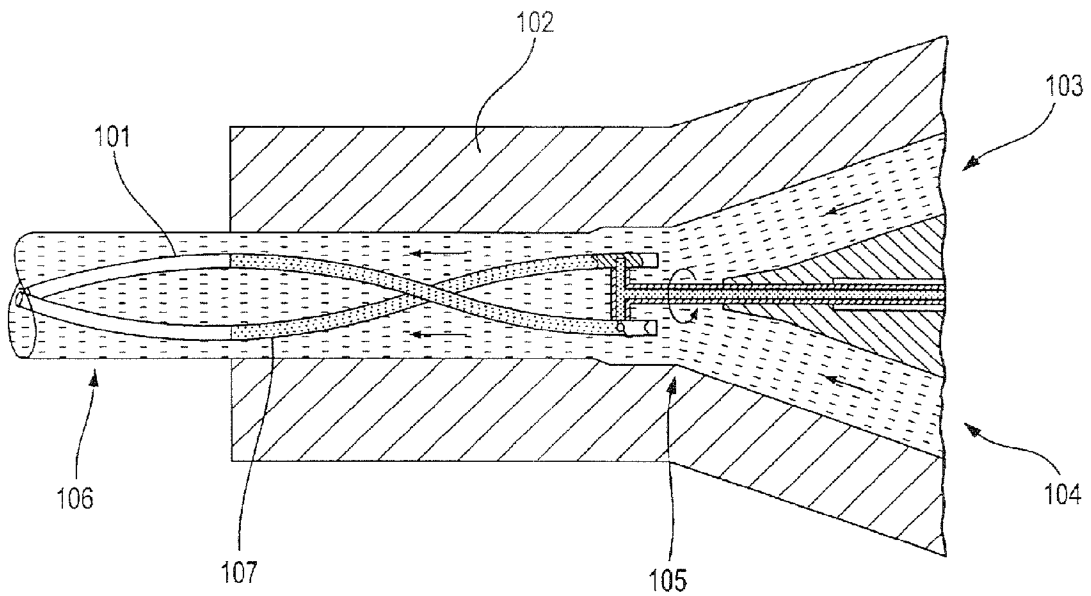
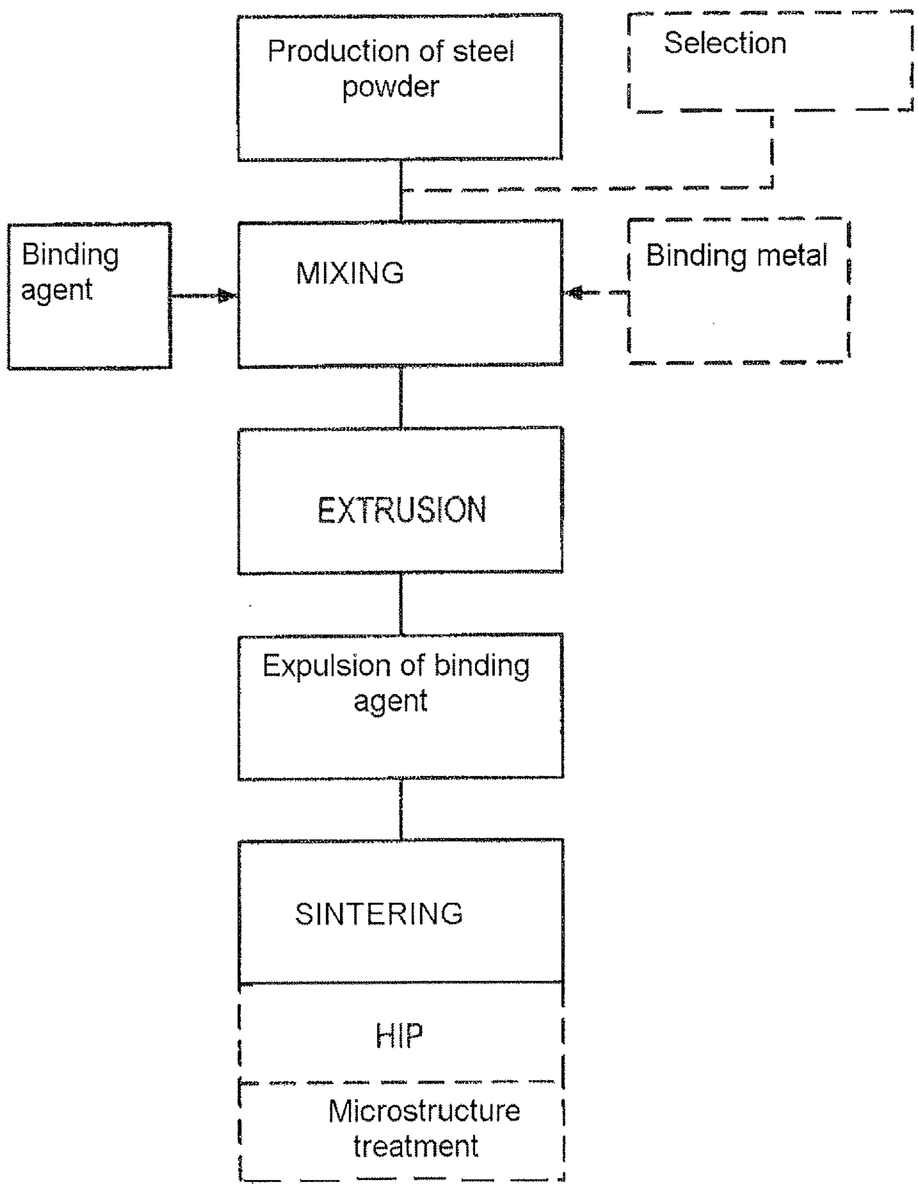


FIG. 1


Production of steel powder
Selection
Binding agent
MIXING
Binding metal
EXTRUSION
Expulsion of binding agent
SINTERING
HIP
Microstructure treatment

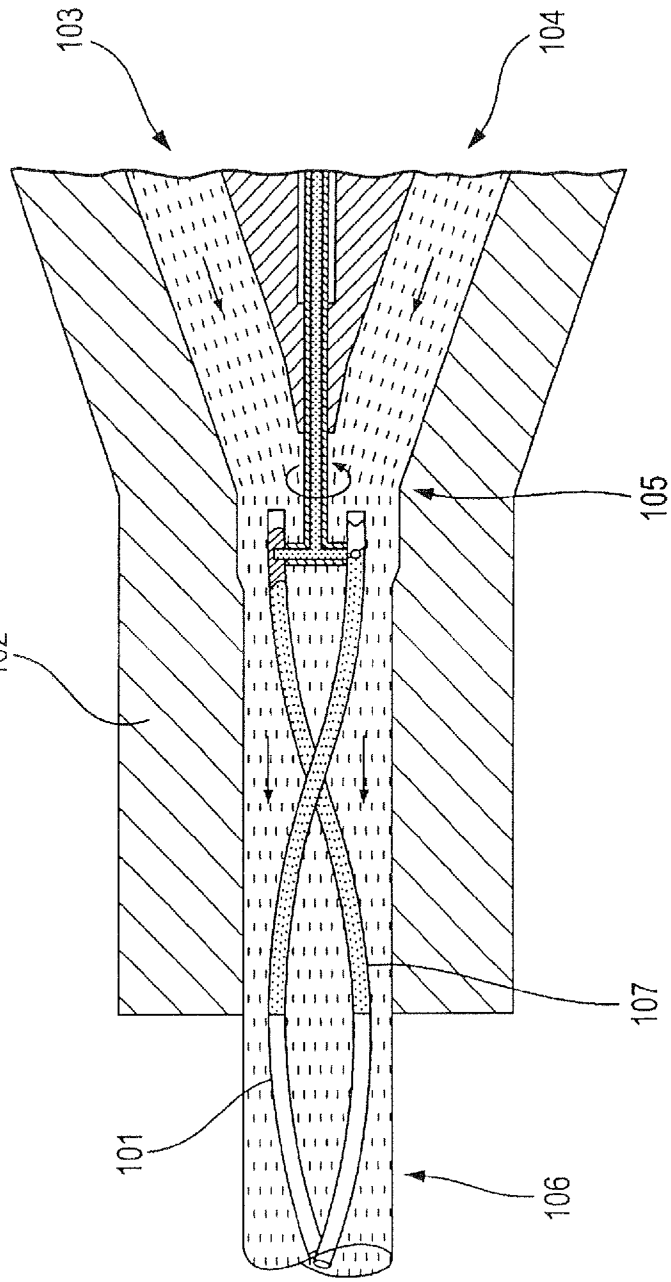


FIG. 2

POWDER-METALLURGICAL STEEL

FIELD OF THE INVENTION

[0001] The present invention relates to a method for producing a powder-metallurgical steel, a raw mixture for producing a steel, a powder-metallurgical steel for producing a tool, and a steel.

BACKGROUND OF THE INVENTION

[0002] In the related art, cylindrical rods for manufacturing cutting tools are produced from HSS or HSS-E by rolling or drawing.

SUMMARY OF THE INVENTION

[0003] Previously, blanks for manufacturing tools have been produced from HSS or HSS-E by rolling or drawing the steel in repeated processing cycles. These processing operations are not only time-intensive, they are also expensive because they require sophisticated equipment and complex processes.

[0004] In contrast to this, blanks can be made from hard metal or cermets using much simpler equipment and processes. Blanks can be produced from hard metal or cermets by extrusion and subsequent sintering. Pertinent manufacturing processes are known from example from U.S. Pat. No. 2,422,994, DE 36 01 385 A1, EP 465 946 A1, EP 1 017 527 B1, EP-A-0 340 495, EP-A-0 458 774, WO-A-92/22390 or US-A-4 779 440.

[0005] The advantage of the extrusion process is that continuous rods can be created thereby, which are favourable for producing drilling, milling, reaming or countersinking tools, because the raw material (green body) can already be formed into the desired cylindrical shape by processing in this way, which can serve as an ideal starting point for manufacturing drilling, milling, reaming or countersinking tools.

[0006] Extruding is also advantageous in that for example internal channels can be arranged inside the extruded rods during extrusion by simple expansions of the extruding nozzle. These inner channels may serve in the finished tool to transport coolants and/or lubricants through the interior of the tool to the cutting section of the tool.

[0007] One object is therefore to provide the capability to obtain rods for manufacturing tools from HSS or HSS-E more simply. A further object is to provide a raw mixture with which such tools may be manufactured inexpensively.

[0008] This object is solved with the method according to claim **1**, the raw mixture according to claim **12**, and with a steel produced from such a raw mixture according to claim **13** or **14**.

[0009] According to the invention, it is possible to manufacture components or semifinished goods having extremely complex shapes from tool steel very inexpensively. The method according to the invention for producing a powder-metallurgical steel, particularly a tool steel such as HSS or HSS-E steel, is characterised in that first steel powder having a predetermined microstructure is produced. A plastically deformable raw mixture is produced by mixing the steel powder with a binding agent such as wax or paraffin, which raw material may directly undergo a preforming process—preferably based on suitable selection of the particle size and/or particle size distribution of the steel powder. In this way, a blank for a steel component having a spatial form of any degree of complexity may be produced without interrupting the process.

[0010] Possibly preceded by a separate step of expelling the binding agent, the actual creation of the microstructure takes place during sintering of the blank, that is to say the steel particles, which are preferably as close to spherical in shape as possible to assist in the extrusion process, are fused and merge closely together, yielding an extremely dense, extremely strong steel component. The microstructure inside the steel powder particles is substantially preserved, so that predictable material properties remain. It has been observed that the pressure that is generated during extrusion through a nozzle is sufficient to produce a blank constituted by a raw mixture of steel/bonding agent of sufficient density and strength following sintering process under approximately atmospheric pressure. Of course, the microstructure may be further improved by implementing a hot isostatic pressing (HIP) process in parallel with or subsequent to the extrusion.

[0011] In order to prepare the raw mixture for the preforming process even better, it is advantageous if the steel powder undergoes processing to homogenize the geometry of the powder particles while and/or before it is mixed with the binding agent.

[0012] In the variation of claim **4**, according to which the steel powder undergoes a sorting process before mixing, so that it is presented for the mixing process in a predefined particle size and/or particle size distribution, it is possible to exercise further positive influence on the strength of the steel microstructure.

[0013] If the steel powder is obtained by grinding or crushing steel particles, the original microstructure of the steel powder may be selected optimally, independently of the production process.

[0014] If the steel powder is also mixed with a binding metal, such as cobalt, the material property of the manufactured steel may also be modified widely.

[0015] In order to produce materials of particularly high density, it is advantageous if the blank undergoes a hot isostatic pressing (HIP) process before, during or after sintering.

[0016] It is particularly advantageous if the blank undergoes thermal treatment, such as a hardening process, to control the steel microstructure during the sintering process. This is carried out by implementing a suitable temperature/time programme that may be selected as needed according to the specifications for a given material.

[0017] With the selection of the steel powder according to the invention, it thus becomes possible to subject the plastically deformable mass to a preferably continuous extrusion process, and yet still guarantee very good microstructure densities of the steel material. In this context, the plastically deformable mass is preferably extruded through an extrusion die with a nozzle to form a continuous rod, which is then cut to the necessary length without interruption. In this way, the blanks may be manufactured very inexpensively.

[0018] Thus, according to the invention a capability is provided for obtaining powder-metallurgical steel more easily. To this end, steel in powder form is processed in similar manner to the process used for manufacturing hard metal, with the addition of a binding agent. The powdered steel with the binding agent is then extruded and sintered.

[0019] A further aspect of the invention consists in the provision of a raw mixture for manufacturing a steel according to claim **12**.

[0020] Advantageous refinements of the invention are described in the other dependent claims.

[0021] According to an exemplary embodiment of the invention, a method is provided in which cobalt is also used as a binding metal.

[0022] In a further embodiment according to the invention, a method is provided in which pressing is carried out in an extrusion die with a nozzle, so that the raw mixture may be extruded to form a continuous rod.

[0023] According to a further embodiment of the present invention, a method is provided in which at least sections of an interior channel are arranged for transporting coolant and/or lubricant during the extrusion process.

[0024] According to an exemplary embodiment of the invention, a method is provided in which at least sections of the interior channel are constructed in the form of a coil or as straight sections.

[0025] In a further embodiment of the invention, a steel is provided wherein the steel may be manufactured from a raw mixture according to claim **6**.

[0026] It may thus be considered a decisive advantage of the invention that powder-metallurgical steel may be manufactured more easily and inexpensively. Besides a tool steel such as HSS-E, a high-alloy steel for example may also serve as the starter material. Or the powder may also be ground by spray forming the steel melt. The manufacture of a powder-metallurgical steel according the invention requires little production equipment and is therefore less expensive during manufacturing than the techniques of the prior art. It is also possible to achieve a higher rate of production than with the manufacturing processes according to the prior art when the method according to the invention is used to produce powder-metallurgical steel.

[0027] Of course, the individual features may also be combined with each other to produce several advantageous effects, which extend beyond the sum of the individual effects.

BRIEF DESCRIPTION OF THE DRAWING

[0028] Further details and advantages of the invention will become evident with reference to the embodiments represented in the drawing. In the drawing:

[0029] FIG. **1** shows a diagram illustrating the steps of the method according to the invention, and

[0030] FIG. **2** shows a nozzle for extruding a continuous powder-metallurgical rod.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0031] It is known from the prior art to use powdered steel in the manufacture of powder-metallurgical steels. This steel is typically a high-alloy steel which may contain for example 0.46% carbon and 13% chromium. In this context, the powdered steel is compacted by repeated rolling. The resulting blocks may be used to manufacture tools, for example. Cooling channel may be provided by introducing drillholes into the partially compacted steel between the first rolling operations. Overall, this method for producing a powder-metallurgical steel requires a substantial commitment in terms of production equipment. The production method according to the prior art is also time-consuming.

[0032] FIG. **1** shows the process workflow according to the invention for manufacturing a powder-metallurgical steel, particularly a tool steel, such as HSS or HSS-E steel. In this process, steel powder is produced in a first process step, wherein the steel powder preferably has a previously selected microstructure, such as the microstructure of a high speed steel in the cast condition, or that of a high speed steel that has already been substantially structured.

[0033] This is followed by the addition of a binding agent such as paraffin or wax to yield a plastically deformable raw mixture, which may immediately undergo further processing in a preforming process. Dotted lines indicate a variant according to which the steel powder is also mixed with a binding metal such as cobalt.

[0034] While it is being mixed with the binding agent and/or before mixing with the binding agent the steel powder may undergo treatment to homogenize the geometry of the powder particles—in a ball mill for example. This removes edges of the powder particles and the particles are rendered essentially spherical, thereby making the subsequent preforming process easier.

[0035] It is also possible and advantageous to subject the steel powder to a selection process before it is mixed, so that it has a predefined particle size and/or particle size distribution when it undergoes the mixing process.

[0036] The raw mixture obtained thereby is now preformed to produce a blank having a predetermined spatial form, preferably using an extrusion die to manufacture blanks having a structure with any degree of spatial complexity.

[0037] The binding agent is expelled at selected temperatures during the subsequent sintering step, or also in a prior work step. This is followed by the actual sintering operation, in which the final steel microstructure is produced. The blank may undergo hot isostatic pressing (HIP) treatment before, during or after sintering. This optional method step is indicated with a dashed line in FIG. **1**.

[0038] According to a further optional variant, the blank may undergo thermal treatment, for example a hardening process, during the sintering process to control the steel microstructure. In this context, the sintering system cycles through a predetermined, temporally controlled thermal profile at the end of which the steel has the desired microstructure quality.

[0039] The steel powder may also be obtained by grinding or crushing steel particles.

[0040] It has been discovered that it is possible to manufacture high-quality steel components from HSS or HSS-E steel if the plastically deformable mass is subjected to a preferably continuous extrusion process, in which the plastically deformable mass is extruded through an extrusion die equipped with a nozzle (**102**)—with relatively little compaction—to form a continuous rod.

[0041] The blanks (green bodies) obtained in the form of a steel/bonding agent mixture in the extrusion step may thus be processed in similar manner to the production of hard metal or cermets. Processing with an extrusion die, which may be equipped with a nozzle for extrusion, and the subsequent sintering operation enable a powder-metallurgical steel to be manufactured simply, rapidly and advantageously. The output form as a continuous rod from the extrusion process is advantageous because the shape may already approximate the geometrical shape of a drilling, milling, countersinking or reaming tool. Steel that exists in powdered form is thus treated and processed according to the invention, for example tungsten carbides as the starting material for manufacturing hard metal (with the addition of a binding agent such as cobalt).

[0042] Since it is possible according to the invention to carry out production using an extrusion process, internal channels may also be conformed in the extruded rod advantageously and simply, particularly the dimensions of which (diameter, circular or elliptical cross section) cannot be modified to the same degree by the subsequent processing operations, such as sintering, as may be the case in comparative terms with the processing method of the prior art, due to rolling, for example. Consequently, a higher degree of dimensional accuracy in the production of interior channels in powder-metallurgical steels may be assured.

[0043] FIG. **1** shows in exemplary manner a nozzle for extruding a continuous rod, wherein a raw mixture is compressed into the nozzle through an inlet aperture **103**, **104** that may have an annular surface area. According to the invention, the raw mixture comprises powdered steel, wherein the steel may also be high alloy steel, and at least one additional binding agent, such as cobalt. The raw mixture is merged in area **105**, wherein twisted interior channels **101** may be conformed in the compacted raw mixture, for example by continuously rotating rods **107**. Then, a continuous rod **106** with interior channels **101** may exit through nozzle **102**. If rods **107** do not rotate but are stationary, continuous rods **106** may be formed with straight interior channels.

[0044] Such extrusion nozzles or nozzles that are usable in such manner are known per se and are described for example in the documents U.S. Pat. No. 2,422,994, DE 36 01 385 A1, EP 465 946 A1, EP 1 017 527 B1, EP-A-0 340 495, EP-A-0 458 774, WO-A-92/22390 or US-A-4 779 440, the disclosed contents of which are explicitly included in the present application.

[0045] The invention thus provides a method for manufacturing a powder-metallurgical steel. The method comprises the following steps: production of steel powder, preferably having a predetermined microstructure; mixing the steel powder with a binding agent to form a plastically deformable raw mixture; performing the raw mixture to form a blank having a predefined spatial form; and sintering the blank.

[0046] It should be noted that the term "comprise" does not preclude other elements or process steps, just as the term "one" or "a (an)" does not preclude several elements and steps.

[0047] The reference signs are intended solely to improve comprehension and should not be considered limiting in any way, wherein the extent of protection for the invention is reflected by the claims.

LIST OF REFERENCE SIGNS

[0048] **101** Interior channel
[0049] **102** Nozzle
[0050] **103** Inlet aperture
[0051] **104** Inlet aperture
[0052] **105** Mixing area
[0053] **106** Extruded rod
[0054] **107** Rod

1. A method for producing a powder-metallurgical steel, particularly a tool steel, such as HSS or HSS-E steel, having the following process steps:
producing steel powder have a predetermined microstructure;
mixing the steel powder with a binding agent to form a plastically deformable raw mixture;
preforming the raw mixture to form a blank having a predefined spatial form; and
sintering the blank.

2. The method according to claim **1**, characterized in that the steel powder undergoes processing to homogenize the geometry of the powder particles while it is being mixed with the binding agent.

3. The method according to claim **1**, characterized in that the steel powder undergoes processing to homogenize the geometry of the powder particles before it is mixed with the binding agent.

4. The method according to claim **3**, characterized in that the steel powder undergoes a selection process before mixing so that it has a predetermined particle size and/or particle size distribution when it undergoes the mixing process.

5. The method according to claim **1**, characterized in that the steel powder is obtained by grinding or crushing steel particles.

6. The method according to claim **1**, characterized in that the steel powder is mixed with a binding agent, for example cobalt.

7. The method according to claim **1**, characterized in that the blank undergoes a hot isostatic pressing (HIP) process before, during or after sintering.

8. The method according to claim **1**, characterized in that the blank undergoes a thermal treatment, for example a hardening process, during the sintering process to control the steel microstructure.

9. The method according to claim **1**, characterized in that the plastically deformable mass undergoes a preferably continuous extrusion process, wherein the plastically deformable mass is extruded through an extrusion die with a nozzle (**102**) to form a continuous rod.

10. The method according to claim **9**, wherein at least sections of an interior channel are arranged for transporting coolant and/or lubricant into the rod.

11. The method according to claim **10**, wherein at least sections of the interior channel are constructed in the form of a coil or as straight sections.

12. A raw mixture for manufacturing a powder-metallurgical steel, particularly a tool steel such as HSS or HSS-E steel, comprising:
steel powder having a predetermined microstructure; and
binding agent mixed therewith in such manner that the raw mixture is suitable for extruding and subsequent sintering.

13. A powder-metallurgical steel for manufacturing a tool, wherein the steel is producible by a method according to claim **1**.

14. The steel according to claim **13**, wherein the steel is producible from a raw mixture comprising steel powder having a predetermined microstructure and binding agent mixed therewith in such manner that the raw mixture is suitable for extruding and subsequent sintering.

15. A component or semifinished product manufactured according to the method according to claim **1** or from a raw mixture comprising steel powder having a predetermined microstructure and binding agent mixed therewith in such manner that the raw mixture is suitable for extruding and subsequent sintering or from a steel producible by (1) producing steel powder have a predetermined microstructure; (2) mixing the steel powder with a binding agent to form a plastically deformable raw mixture; (3) preforming the raw mixture to form a blank having a predefined spatial form; and (4) sintering the blank.

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