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(54) **MANUFACTURE OF LOW COST BITS BY INFILTRATION OF METAL POWDERS**

(57) An apparatus and method for manufacturing a downhole tool. The cemented matrix material is formed from a metal powder, a shoulder powder, and a binder material, wherein the metal powder and/or the shoulder powder includes at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or powders of other suitable metals or alloys, or a combination of such mentioned powders.

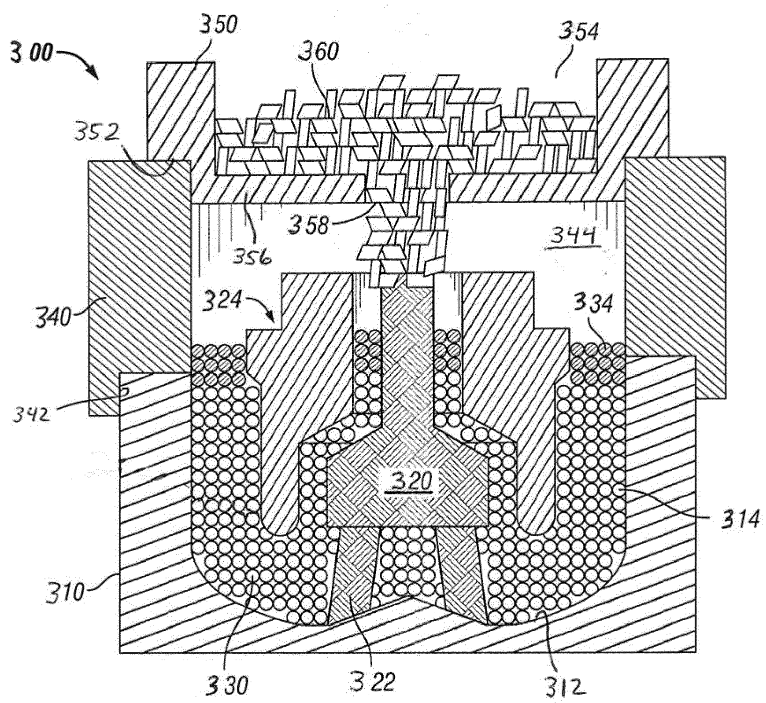

FIG. 3

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This present application claims priority to U. S. Provisional Patent Application No. 61/943,141, entitled "Manufacture Of Low Cost Bits By Infiltration Of Metal Powders," filed February 21, 2014, the disclosure of which is incorporated herein.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to downhole tools and methods for manufacturing such items. More particularly, this invention relates to low cost infiltrated metal powders used in drilling products including, but not limited to, fixed cutter bits, polycrystalline diamond compact ("PDC") drill bits, natural diamond drill bits, thermally stable polycrystalline ("TSP") drill bits, bi-center bits, core bits, and reamers and stabilizers, and the methods of manufacturing such items.

[0003] Full hole tungsten carbide matrix drill bits for oilfield applications have been manufactured and used in drilling since at least as early as the 1940's. Figure 1 shows a cross-sectional view of a downhole tool casting assembly 100 in accordance with the prior art. The downhole tool casting assembly 100 consists of a thick-walled mold 110, a stalk 120, one or more nozzle displacements 122, a blank 124, a funnel 140, and a binder pot 150. The downhole tool casting assembly 100 is used to fabricate a casting 200 (Figure 2) of a downhole tool 200 (Figure 2), such as a drill bit 200 (Figure 2).

[0004] According to a typical downhole tool casting assembly 100, as shown in Figure 1, and a method for using the downhole tool casting assembly 100, the thick-walled mold 110 is fabricated with a precisely machined interior surface 112, and forms a mold volume 114 located within the interior of the thick-walled mold 110. The thick-walled mold 110 is made from sand, hard carbon graphite, ceramic, or other known suitable materials. The precisely machined interior surface 112 has a shape that is a negative of what will become the facial features of the eventual bit face. The precisely machined interior surface 112 is milled and dressed to form the proper contours of the finished bit 200 (Figure 2). Various types of cutters 240 (Figure 2), known to persons having ordinary skill in the art, can be placed along the locations of the cutting edges of the bit 200 (Figure 2) and can also be optionally placed along the gauge area 250 (Figure 2) of the bit 200 (Figure 2). These cutters 240 (Figure 2) can be placed during the bit fabrication process or after the bit 200 (Figure 2) has been fabricated via brazing or other methods known to persons having ordinary skill in the art.

[0005] Once the thick-walled mold 110 is fabricated, displacements are placed at least partially within the mold volume 114 of the thick-walled mold 110. The displacements are typically fabricated from clay, sand, graphite, ceramic, or other known suitable materials. These displacements consist of the center stalk 120 and the at least one nozzle displacement 122. The center stalk 120 is positioned substantially within the center of the thick-walled mold 110 and suspended a desired distance from the bottom of the mold's interior surface 112. The nozzle displacements 122 are positioned within the thick-walled mold 110 and extend from the center stalk 120 to the bottom of the mold's interior surface 112. The center stalk 120 and the nozzle displacements 122 are later removed from the eventual drill bit casting 200 (Figure 2) so that drilling fluid (not shown) can flow though the center of the finished bit 200 (Figure 2) during the drill bit's operation.

[0006] The blank 124 is a cylindrical steel casting mandrel that is centrally suspended at least partially within the thick-walled mold 110 and around the center stalk 120. The blank 124 is positioned a predetermined distance down in the thick-walled mold 110. According to the prior art, the distance between the outer surface of the blank 124 and the interior surface 112 of the thick-walled mold 110 is typically twelve millimeters ("mm") or more so that potential cracking of the thick-walled mold 110 is reduced during the casting process.

[0007] Once the displacements 120, 122 and the blank 124 have been positioned within the thick-walled mold 110, tungsten carbide powder 130, which includes some free tungsten, is loaded into the thick-walled mold 110 so that it fills a portion of the mold volume 114 that is around the lower portion of the blank 124, between the inner surfaces of the blank 124 and the outer surfaces of the center stalk 120, and between the nozzle displacements 122. Shoulder powder 134 is loaded on top of the tungsten carbide powder 130 in an area located at both the area outside of the blank 124 and the area between the blank 124 and the center stalk 120. The shoulder powder 134 is made of tungsten powder. This shoulder powder 134 acts to blend the casting to the steel blank 124 and is machinable. Once the tungsten carbide powder 130 and the shoulder powder 134 are loaded into the thick-walled mold 110, the thick-walled mold 110 is typically vibrated to improve the compaction of the tungsten carbide powder 130 and the shoulder powder 134. Although the thick-walled mold 110 is vibrated after the tungsten carbide powder 130 and the shoulder powder 134 are loaded into the thick-walled mold 110, the vibration of the thick-walled mold 110 can be done as an intermediate step before, during, and/or after the shoulder powder 134 is loaded on top of the tungsten carbide powder 130.

[0008] The funnel 140 is a graphite cylinder that forms a funnel volume 144 therein. The funnel 140 is coupled to the top portion of the thick-walled mold 110. A recess 142 is formed at the interior edge of the funnel 140, which facilitates the funnel 140 coupling to the upper portion of the thick-walled mold 110. Typically, the inside diameter of the thick-walled mold 110 is similar to the inside diameter of the funnel 140 once the funnel 140 and the thick-walled mold 110 are coupled together.

[0009] The binder pot 150 is a cylinder having a base 156 with an opening 158 located at the base 156, which extends through the base 156. The binder pot 150 also forms a binder pot volume 154 therein for holding a binder material 160. The binder pot 150 is coupled to the top portion of the funnel 140 via a recess 152 that is formed at the exterior edge of the binder pot 150. This recess 152 facilitates the binder pot 150 coupling to the upper portion of the funnel 140. Once the downhole tool casting assembly 100 has been assembled, a predetermined amount of binder material 160 is loaded into the binder pot volume 154. The typical binder material 160 is a copper alloy or other suitable known material and may include some flux powder. Although one example has been provided for setting up the downhole tool casting assembly 100, other examples can be used to form the downhole tool casting assembly 100. For example, the mold 110 and the funnel 140 are formed as a single component.

[0010] The downhole tool casting assembly 100 is placed within a furnace (not shown) or other heating structure. The binder material 160 melts and flows into the tungsten carbide powder 130 through the opening 158 of the binder pot 150. In the furnace, the molten binder material 160 infiltrates the tungsten carbide powder 130 and the shoulder powder 134 to fill the interparticle spaces formed between adjacent particles of tungsten carbide powder 130 and between adjacent particles of shoulder powder 134. During this process, a substantial amount of binder material 160 is used so that it fills at least a substantial portion of the funnel volume 144. This excess binder material 160 in the funnel volume 144 supplies a downward force on the tungsten carbide powder 130 and the shoulder powder 134. Once the binder material 160 completely infiltrates the tungsten carbide powder 130 and the shoulder powder 134, the downhole tool casting assembly 100 is pulled from the furnace and is controllably cooled. Upon cooling, the binder material 160 solidifies and cements the particles of tungsten carbide powder 130 and the shoulder powder 134 together into a coherent integral mass (not shown). The binder material 160 also bonds this coherent integral mass to the steel blank 124. The coherent integral mass and the blank 124 collectively form the matrix body bit 200 (Figure 2). Once cooled, the thick-walled mold 110 is broken away from the casting 200 (Figure 2). The casting 200 (Figure 2) then undergoes finishing steps which are known to persons having ordinary skill in the art, including the addition of a threaded connection 220 (Figure 2) coupled to the top portion of the blank 124. Although the matrix body bit 200 (Figure 2), or casting 200 (Figure 2), has been described to be formed using the process and equipment described above, the process and/or the equipment can be varied to form the matrix body bit 200 (Figure 2).

[0011] Figure 2 shows a perspective view of a conventional drill bit 200, or conventional fixed cutter drill bit 200, in accordance with the prior art. Referring to Figure 2, the conventional drill bit 200 includes a bit body 210 that is coupled to the shank 124 and is designed to rotate in a counter-clockwise direction 290. The shank 124 is coupled to an API connection 216 which includes a threaded connection 217 at one end 220. The threaded connection 217 couples to a drill string (not shown) or some other equipment that is coupled to the drill string. The threaded connection 217 is shown to be positioned on the exterior surface of the one end 220. This positioning assumes that the conventional drill bit 200 is coupled to a corresponding threaded connection located on the interior surface of a drill string (not shown). However, the threaded connection 217 at the one end 220 is alternatively positioned on the interior surface of the one end 220 if the corresponding threaded connection of the drill string, or other equipment, is positioned on its exterior surface in other exemplary embodiments. A bore (not shown) is formed longitudinally through the shank 124 and extends into the bit body 210 forming a plenum (not shown), which communicates drilling fluid during drilling operations from within the bit body 210 to a drill bit face 211 via one or more conventional nozzle sockets 214 formed within the bit body 210. These conventional nozzle sockets 214 are cylindrically shaped within the conventional drill bit 200.

[0012] The bit body 210 includes a plurality of gauge sections 250 and a plurality of blades 230 extending from the drill bit face 211 of the bit body 210 towards the threaded connection 217, where each blade 230 extends to and terminates at a respective gauge section 250. The blade 230 and the respective gauge section 250 are formed as a single component, but are formed separately in certain other conventional drill bits 200. The drill bit face 211 is positioned at one end of the bit body 210 furthest away from the shank 124. The plurality of blades 230 form the cutting surface of the conventional drill bit 200. One or more of these plurality of blades 230 are either coupled to the bit body 210 or are integrally formed with the bit body 210. The gauge sections 250 are positioned at an end of the bit body 210 adjacent the shank 124. The gauge section 250 includes one or more gauge cutters (not shown) in certain conventional drill bits 200. The gauge sections 250 typically define and hold the full hole diameter of the drilled hole. The blades 230 and/or the gauge sections 250 are oriented in a spiral configuration according to some of the prior art. However, in other conventional drill bits, the blades 230 and/or the gauge sections 250 are oriented in a non-spiral configuration. A junk slot 222 is formed, or milled, between each consecutive blade 230, which allows for cuttings and drilling fluid to return to the surface of the wellbore (not shown) once the drilling fluid is discharged from the nozzle sockets 214 during drilling operations.

[0013] A plurality of cutters 240 are coupled to each of the blades 230 within a respective cutter pocket 260 formed therein. The cutters 240 are generally formed in an elongated cylindrical shape; however, these cutters 240 can be formed in other shapes, such as disc-shaped or conical-shaped. The cutters 240 typically include a substrate 242, oftentimes cylindrically shaped, and a cutting surface 244, also cylindrically shaped, disposed at one end of the substrate 242 and oriented to extend outwardly from the blade 230 when coupled within the respective cutter pocket 260. The cutting surface 244 can be formed from a hard material, such as bound particles of polycrystalline diamond forming a diamond table, and be disposed on or coupled to a substantially circular profiled end surface of the substrate 242 of each cutter 240. Typically, the polycrystalline diamond cutters ("PDC") are fabricated separately from the bit body 210 and are secured within a respective cutter pocket 260 formed within the bit body 210. Although one type of cutter 240 used within the conventional drill bit 200 is a PDC cutter; other types of cutters also are contemplated as being used within the conventional drill bit 200. These cutters 240 and portions of the bit body 210 deform the earth formation by scraping and/or shearing depending upon the type of conventional drill bit 200.

[0014] The tungsten carbide matrix used in forming the drill bit 200 is very brittle, not hard, and not ductile; thereby causing eventual failure of the bit 200 during drilling operations. Further, the cost of tungsten carbide 130 (Figure 1) and tungsten 134 (Figure 1) powders used in forming the drill bit 200 are relatively expensive. There is a need to fabricate downhole tools using cheaper materials, either alone or in combination with the tungsten carbide 130 (Figure 1) and/or tungsten 134 (Figure 1) powders thereby using less tungsten carbide 130 (Figure 1) and/or tungsten 134 (Figure 1) powders and making the bit 200 lower costing. Further, there is a need to use other materials in fabricating these downhole tools to modify the properties of the coherent integral mass, or bit body 210, allowing the downhole tool 200 perform better and last longer in the hole.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The foregoing and other features and aspects of the invention will be best understood with reference to the following description of certain exemplary embodiments of the invention, when read in conjunction with the accompanying drawings, wherein:

Figure 1 shows a cross-sectional view of a downhole tool casting assembly in accordance with the prior art;

Figure 2 shows a perspective view of a conventional fixed cutter drill bit in accordance with the prior art;

Figure 3 shows a cross-sectional view of a downhole tool casting assembly in accordance with an exemplary embodiment of the invention; and

Figure 4 shows a partial cross-sectional view of a downhole tool casting formed using the downhole tool casting assembly of Figure 3 in accordance with the exemplary embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0016] This invention relates generally to downhole tools and methods for manufacturing such items. More particularly, this invention relates to low cost infiltrated metal powders used in drilling products including, but not limited to, fixed cutter bits, polycrystalline diamond compact ("PDC") drill bits, natural diamond drill bits, thermally stable polycrystalline ("TSP") drill bits, bi-center bits, core bits, and reamers and stabilizers, and the methods of manufacturing such items. Although the description provided below is related to a drill bit, embodiments of the present invention relate to any infiltrated metal powders used to fabricate a drilling product.

[0017] Figure 3 shows a cross-sectional view of a downhole tool casting assembly 300 in accordance with the exemplary embodiment. Referring to Figure 3, the downhole tool casting assembly 300 includes a mold 310, a stalk 320, one or more nozzle displacements 322, a blank 324, a funnel 340, and a binder pot 350. The downhole tool casting assembly 300 is used to fabricate a casting 400 (Figure 4) of a downhole tool, such as a fixed cutter bit, a PDC drill bit, a natural diamond drill bit, and a TSP drill bit. However, the downhole tool casting assembly 300 is modified in other exemplary embodiments to fabricate other downhole tools, such as a bi-center bit, a core bit, and a matrix bodied reamer and stabilizer.

[0018] The mold 310 is fabricated with a precisely machined interior surface 312, and forms a mold volume 314 located within the interior of the mold 310. The mold 310 is made from sand, hard carbon graphite, ceramic, or other known suitable materials. The precisely machined interior surface 312 has a shape that is a negative of what will become the facial features of the eventual bit face. The precisely machined interior surface 312 is milled and dressed to form the proper contours of the finished bit. Various types of cutters, such as the cutters 240 (Figure 2), known to persons having ordinary skill in the art, are placed along the locations of the cutting edges of the bit and are optionally placed along the gage area of the bit. These cutters are placed during the bit fabrication process or after the bit has been fabricated via brazing or other methods known to persons having ordinary skill in the art.

[0019] Once the mold 310 is fabricated, displacements are placed at least partially within the mold volume 314. The displacements are fabricated from clay, sand, graphite, ceramic, or other known suitable materials. These displacements include the center stalk 320 and the at least one nozzle displacement 322. The center stalk 320 is positioned substantially within the center of the mold 310 and suspended a desired distance from the bottom of the mold's interior surface 312. The nozzle displacements 322 are positioned within the mold 310 and extend from the center stalk 320 to the bottom of the mold's interior surface 312. The center stalk 320 and the nozzle displacements 322 are later removed from the eventual drill bit casting so that drilling fluid (not shown) flows though the center of the finished bit during the drill bit's operation.

[0020] The blank 324, which has been previously described above with respect to blank 124, is centrally suspended at least partially within the mold 310 and around the center stalk 320. The blank 324 is positioned a predetermined distance down in the mold 310. The distance between the outer surface of the blank 324 and the interior surface 312 of the mold 310 is about twelve millimeters or more so that potential cracking of the mold 310 is reduced during the casting process. However, this distance is varied in other exemplary embodiments depending upon the strength of the mold 310 or the method and/or equipment used in fabricating the casting. According to some exemplary embodiments, a coating (not shown) may optionally be applied to at least a portion of the surface of the blank 324. This coating may be applied to improve the bonding between the powders 330, 334, which are described in more detail below, and the blank 324.

[0021] Once the displacements 320, 322 and the blank 324 have been positioned within the mold 310, metal powder 330 is loaded into the mold 110 so that it fills a portion of the mold volume 314 that is around at least a lower portion of the blank 324, between the inner surfaces of the blank 324 and the outer surfaces of the center stalk 320, and between the nozzle displacements 322. Shoulder powder 334 is loaded on top of the metal powder 330 in an area located at both the area outside of the blank 324 and the area between the blank 324 and the center stalk 320. According to some exemplary embodiments, the metal powder 330 and the shoulder powder 334 are the same powders with the same or similar compositions. However, in other exemplary embodiments, the metal powder 330 and the shoulder powder 334 are different powders, having some or none of the powder materials being the same. Also, the metal powder 330 and the shoulder powder 334 may have the same material but at a different composition, according to some exemplary embodiments.

[0022] According to some exemplary embodiments, the metal powder 330 includes at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or powders of other suitable metals or alloys, or a combination of such mentioned powders. According to some exemplary embodiments, the metal powder 330 is formed of at least more than 25% of at least one of these powders mentioned immediately above. For example, the metal powder 330 is formed of at least more than 25% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of such mentioned powders. According to some other exemplary embodiments, the metal powder 330 is formed of at least more than 30% of at least one of these powders mentioned immediately above. In yet other exemplary embodiments, the metal powder 330 is formed of at least more than 40% of at least one of these powders mentioned immediately above. In an alternative exemplary embodiment, the metal powder 330 is formed with less than 25% of tungsten carbide powders. In yet another alternative exemplary embodiment, the metal powder 330 is formed with less than 20% of tungsten carbide powders. In yet another exemplary embodiment, the metal powder 330 is formed with less than 15% of tungsten carbide powders.

[0023] According to some exemplary embodiments, the shoulder powder 334 includes at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or powders of other suitable metals or alloys, or a combination of such mentioned powders. According to some exemplary embodiments, the shoulder powder 334 is formed of at least more than 25% of at least one of these powders mentioned immediately above. For example, the shoulder powder 334 is formed of at least more than 25% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of such mentioned powders. According to some other exemplary embodiments, the shoulder powder 334 is formed of at least more than 30% of at least one of these powders mentioned immediately above. In yet other exemplary embodiments, the shoulder powder 334 is formed of at least more than 40% of at least one of these powders mentioned immediately above. In an alternative exemplary embodiment, the shoulder powder 334 is formed with less than 25% of tungsten powders. In yet another alternative exemplary embodiment, the shoulder powder 334 is formed with less than 20% of tungsten powders. In yet another exemplary embodiment, the shoulder powder 334 is formed with less than 15% of tungsten powders.

[0024] Once the metal powder 330 and the shoulder powder 334 are loaded into the mold 310, the mold 310 is vibrated, in some exemplary embodiments, to improve the compaction of the tungsten carbide powder 330 and the shoulder powder 334. Although the mold 310 is vibrated after the metal powder 330 and the shoulder powder 334 are loaded into the mold 310, the vibration of the mold 310 is done as an intermediate step before, during, and/or after the shoulder powder 334 is loaded on top of the metal powder 330.

[0025] The funnel 340 is a graphite cylinder that forms a funnel volume 344 therein. The funnel 340 is coupled to the top portion of the mold 310. A recess 342 is formed at the interior edge of the funnel 340, which facilitates the funnel 340 coupling to the upper portion of the mold 310. In some exemplary embodiments, the inside diameter of the mold 310 is similar to the inside diameter of the funnel 340 once the funnel 340 and the mold 310 are coupled together.

[0026] The binder pot 350 is a cylinder having a base 356 with an opening 358 located at the base 356, which extends through the base 356. The binder pot 350 also forms a binder pot volume 354 therein for holding a binder material 360. The binder pot 350 is coupled to the top portion of the funnel 340 via a recess 352 that is formed at the exterior edge of the binder pot 350. This recess

352 facilitates the binder pot 350 coupling to the upper portion of the funnel 340. Once the downhole tool casting assembly 300 has been assembled, a predetermined amount of binder material 360 is loaded into the binder pot volume 354. The typical binder material 360 is a copper alloy or other suitable known material. According to some exemplary embodiments, the binder material 360, or braze material, includes MF53 and a small amount of B-1 dry Handyflo flux powder, which are known to people having ordinary skill in the art. Although one example has been provided for setting up the downhole tool casting assembly 300, other examples having greater, fewer, or different components are used to form the downhole tool casting assembly 300. For instance, the mold 310 and the funnel 340 are combined into a single component in some exemplary embodiments.

[0027] The downhole tool casting assembly 300 is placed within a furnace (not shown) or other heating structure to undergo a brazing process. During the brazing process, the binder material 360 melts and flows into the shoulder powder 334 and the metal powder 330 through the opening 358 of the binder pot 350. In the furnace, the molten binder material 360 infiltrates the metal powder 330 and the shoulder powder 334 to fill the interparticle spaces formed between adjacent particles of metal powder 330 and/or shoulder powder 334. During this process, a substantial amount of binder material 360 is used so that it fills at least a substantial portion of the funnel volume 344. This excess binder material 360 in the funnel volume 344 supplies a downward force on the metal powder 330 and the shoulder powder 334. According to some exemplary embodiments, the brazing process is performed in air atmosphere at a brazing temperature in excess of 2100 °F and for a time commensurate with the downhole tool 400 (Figure 4), or bit, size. For example, for a 8" bit size, the downhole tool casting assembly 300 is placed at a temperature in of 2100 °F for about one hour.

[0028] Once the binder material 360 completely infiltrates the metal powder 330 and the shoulder powder 334, the downhole tool casting assembly 300 is pulled from the furnace and is controllably cooled. Upon cooling, the binder material 360 solidifies and cements the particles of metal powder 330 and shoulder powder 334 together into a coherent integral mass 410 (Figure 4). The binder material 360 also bonds this coherent integral mass 410 (Figure 4) to the blank 324, according to certain exemplary embodiments. The coherent integral mass 410 (Figure 4) and the blank 324 collectively form the infiltrated bit 400 (Figure 4), a portion of which is shown in Figures 4. Once cooled, the mold 310 is broken away from the casting. The casting then undergoes finishing steps which are known to persons of ordinary skill in the art, including cleaning of the casting and the coupling of a threaded connection (not shown) or AISI 4140 upper section, similar to API connection 216 (Figure 2), to the top portion of the blank 324. According to certain exemplary embodiments, the AISI 4140 upper section is welded to the blank 324 by submerged arc welding ("SAW") or gas metal arc welding ("GMAW") according to the usual method of manufacture. Further, according to some exemplary embodiments, a protective layer of plasma transferred ARC ("PTA") is applied onto at least a portion of the downhole tool, such as the surface of the blades, so that the downhole tool can better handle abrasion. Although the infiltrated bit 400 (Figure 4) has been described to be formed using the process and equipment described above, the process and/or the equipment can be varied to still form the infiltrated bit 400 (Figure 4).

[0029] Figure 4 shows a partial cross-sectional view of a downhole tool casting 400 formed using the downhole tool casting assembly 300 of Figure 3 in accordance with the exemplary embodiment. Referring to Figure 4, the downhole tool casting 400 includes the coherent integral mass 410, the blank 324, and the passageways 420 formed from the removal of the displacements 320, 322 (Figure 3). As mentioned above with respect to Figure 3, the coherent integral mass 410 is formed using the metal powder 330 (Figure 3), as described above, and the shoulder powder 334 (Figure 3), also as described above. The metal powder 330 (Figure 3) and the shoulder powder 334 (Figure 3) are infiltrated with binder material 360 (Figure 3) to form infiltrated metal powder 430 and infiltrated shoulder powder 434, respectively. According to the exemplary embodiment illustrated in Figures 3 and 4, the infiltrated shoulder powder 434 may be of the same or different composition and/or of the same or different powder materials than the infiltrated metal powder 430.

[0030] According to exemplary embodiments, the metal powders and/or the shoulder powders used to manufacture the downhole tool provide improved characteristics than those used in the prior art. As previously mentioned, the tungsten carbide powder has been used in lieu of the above described metal powders and tungsten powder has been used in lieu of the shoulder powder mentioned above. When testing an infiltrated nickel sample using a Charpy test, the force needed to break the sample was found to be 9 ft-lbs, while the force needed to break tungsten carbide matrix sample was 1 ft-lbs at the same conditions. Thus, the infiltrated nickel sample was found to be about 9 times stronger. Similarly, an infiltrated stainless steel sample was found to need 50 ft-lbs to break the sample at the same conditions, thereby making it about 50 times stronger than the tungsten carbide matrix sample. Further, the infiltrated nickel sample was found to have a hardness of HBW 84, whereas the tungsten carbide matrix sample is very brittle that hardness tests are generally not performed on it. The infiltrated stainless steel sample was found to have a hardness of HBW 103. With respect to ductile tests, the infiltrated nickel sample was found to be more ductile than the tungsten carbide matrix sample, and the infiltrated stainless steel sample was found to be more ductile than the infiltrated nickel sample. The infiltrated nickel sample was found to have a yield lbs. of 1,160, an ultimate load lbs. of 2,730, a yield P.S.I. of 24,200 and a tensile P.S.I. of

57,000, while the infiltrated stainless steel sample was found to have a yield lbs. of 2,330, an ultimate load lbs. of 4,470, a yield P.S.I. of 47,900, and a tensile P.S.I. of 91,700. Both nickel powder and stainless steel powder are cheaper than those powders presently used.

[0031] Although the invention has been described with reference to specific embodiments, these descriptions are not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention will become apparent to persons skilled in the art upon reference to the description of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. It is therefore, contemplated that the claims will cover any such modifications or embodiments that fall within the scope of the invention.

Claims

1. A downhole tool, comprising:

a metal component comprising a top portion, a bottom portion, and a channel extending from the top portion to the bottom portion; and
an infiltrated metal powder bonded to an exterior surface and an interior surface of the metal component, the infiltrated metal powder formed from infiltration of a binder material with a metal powder, the infiltrated metal powder coupled to at least the bottom portion of the metal component;
an infiltrated shoulder powder bonded to an exterior surface and an interior surface of the metal component, the infiltrated shoulder powder formed from infiltration of the binder material with a shoulder powder, the infiltrated shoulder powder coupled to at least the top portion of the metal component, the infiltrated shoulder powder being positioned above the infiltrated metal powder,
wherein at least one of the metal powder or shoulder powder used for fabricating the downhole tool comprises:

at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders; and
a concentration of less than 25% of a tungsten carbide powder or a tungsten powder, respectively.

2. The downhole tool of Claim 1, wherein the metal powder comprises at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders and a concentration of less than 25% of the tungsten carbide powder or
wherein the shoulder powder comprises at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders and a concentration of less than 25% of the tungsten powder or
wherein the metal powder and the shoulder powder comprise at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders and a concentration of less than 25% of the tungsten carbide powder and the tungsten powder, respectively or
wherein the metal powder is the same composition as the shoulder powder.

3. The downhole tool of Claim 1, wherein the metal powder is a different composition than the shoulder powder.

4. The downhole tool of Claim 6, wherein the metal powder and the shoulder powder comprise the same powders.

5. The downhole tool of Claim 1, wherein the metal powder is formed of at least more than 25% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or
wherein the metal powder is formed of at least more than 30% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or
wherein the metal powder is formed of at least more than 40% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders.

6. The downhole tool of Claim 1, wherein the shoulder powder is formed of at least more than 25% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or
wherein the shoulder powder is formed of at least more than 30% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or
wherein the shoulder powder is formed of at least more than 40% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders.

7. The downhole tool of Claim 1, wherein at least one of the metal powder or the shoulder powder comprise a concentration of less than 20% of a tungsten carbide powder or a tungsten powder, respectively or wherein at least one of the metal powder or the shoulder powder comprise a concentration of less than 15% of a tungsten carbide powder or a tungsten powder, respectively.

8. A method for manufacturing a downhole tool, comprising:

placing a blank within a downhole tool casting assembly, the blank comprising a top portion, a bottom portion, and a channel extending from the top portion to the bottom portion;
placing a mixture around at least a portion of the surface of the blank within the downhole tool casting assembly, the mixture comprising a metal powder and a shoulder powder, the metal powder positioned adjacent at least the bottom portion of the blank and the shoulder powder being positioned adjacent to at least the top portion of the blank, the shoulder powder being positioned above the metal powder;
melting a binder material into the mixture;
forming an infiltrated metal powder and an infiltrated shoulder powder from the mixture and the binder material; and
bonding the infiltrated metal powder and the infiltrated shoulder powder to the blank,
wherein at least one of the metal powder or shoulder powder used for fabricating the downhole tool comprises:

at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders; and
a concentration of less than 25% of a tungsten carbide powder or a tungsten powder, respectively.

9. The method of Claim 8, wherein the metal powder comprises at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders and a concentration of less than 25% of the tungsten carbide powder or, wherein the shoulder powder comprises at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders and a concentration of less than 25% of the tungsten powder.

10. The method of Claim 8, wherein the metal powder and the shoulder powder comprise at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders and a concentration of less than 25% of the tungsten carbide powder and the tungsten powder, respectively or

11. The method of Claim 16, wherein the metal powder is the same composition as the shoulder powder or wherein the metal powder is a different composition than the shoulder powder or
wherein the metal powder and the shoulder powder comprise the same powders.

12. The method of Claim 8, wherein the metal powder is formed of at least more than 25% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or, wherein the metal powder is formed of at least more than 30% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or
wherein the metal powder is formed of at least more than 40% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders.

13. The method of Claim 8, wherein the shoulder powder is formed of at least more than 25% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or, wherein the shoulder powder is formed of at least more than 30% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders or
wherein the shoulder powder is formed of at least more than 40% of at least one of stainless steel powder, nickel powder, cobalt powder, iron powder, or a combination of two or more of these powders.

14. The method of Claim 8, wherein at least one of the metal powder or the shoulder powder comprise a concentration of less than 20% of a tungsten carbide powder or a tungsten powder, respectively or
wherein at least one of the metal powder or the shoulder powder comprise a concentration of less than 15% of a tungsten carbide powder or a tungsten powder, respectively.

15. The method of Claim 8, further comprising applying a hardfacing material onto at least a portion of the downhole tool.

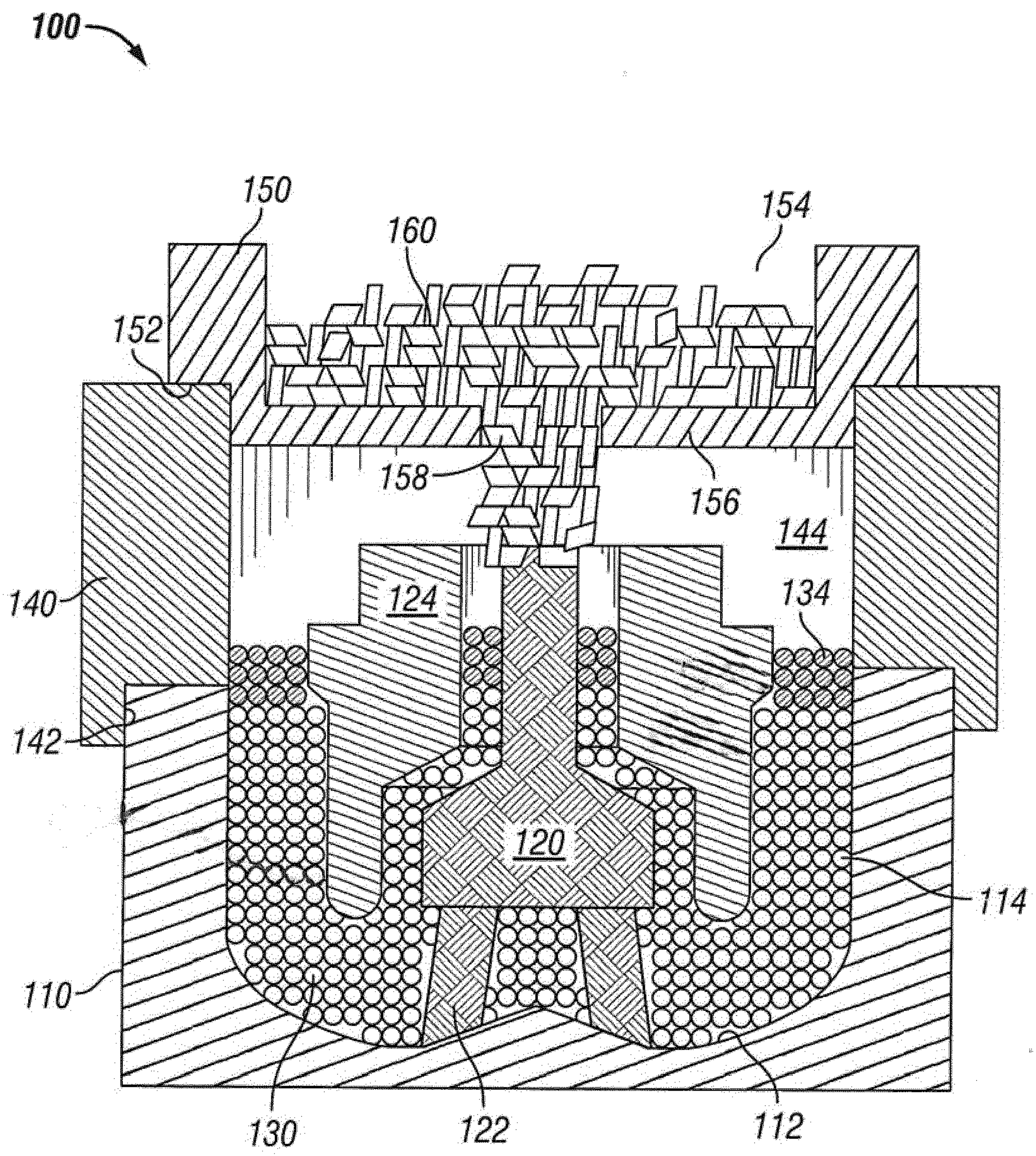

FIG. 1
(Prior Art)

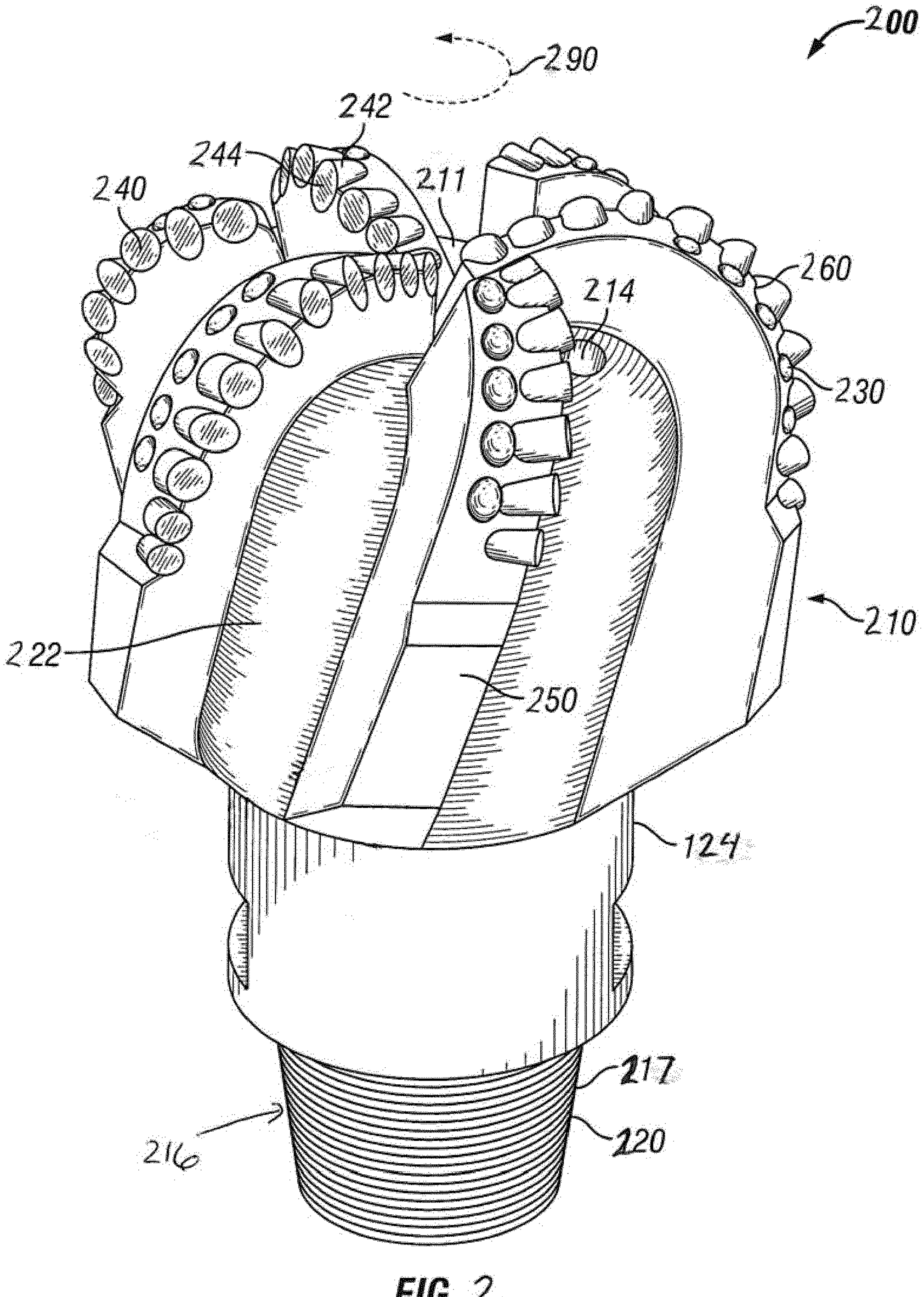

FIG. 2
(Prior Art)

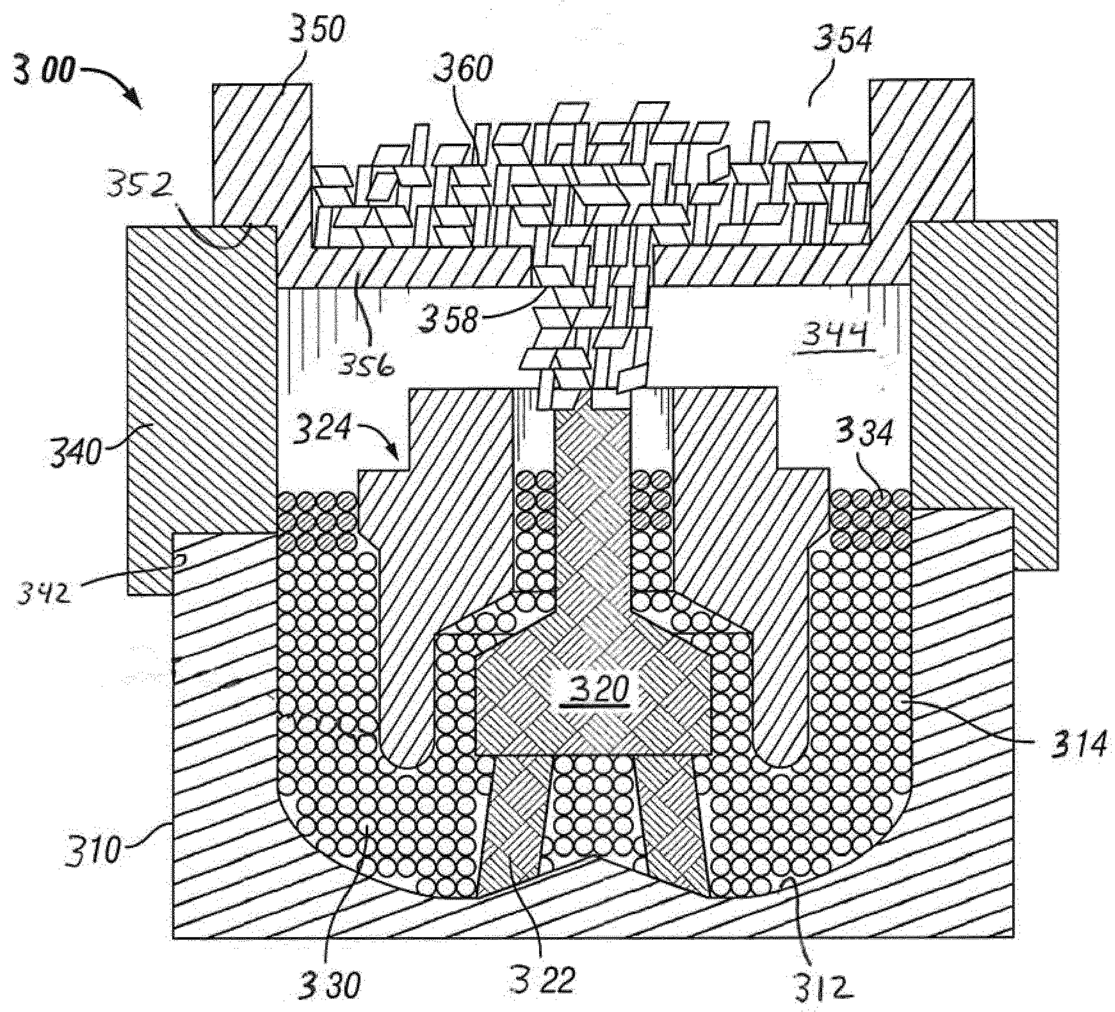
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FIG. 3

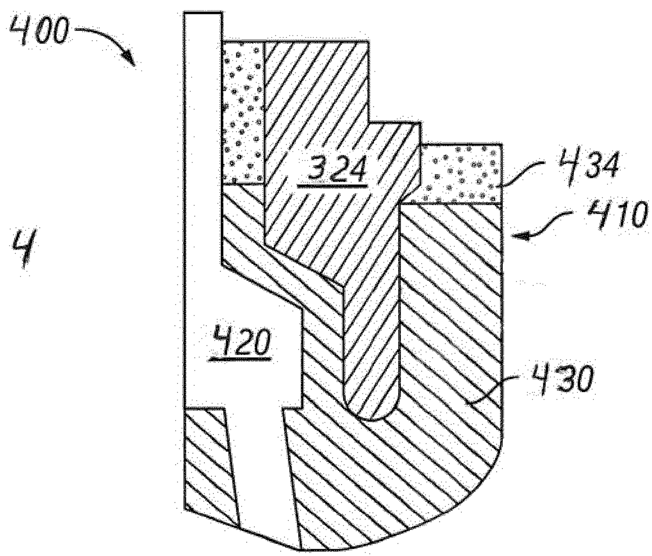
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FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 61943141 A **[0001]**