

PATENT SPECIFICATION

(11)

1 435 045

1 435 045

- (21) Application No. 22084/74 (22) Filed 17 May 1974
(31) Convention Application No. 387 566 (32) Filed 10 Aug. 1973 in
(33) United States of America (US)
(44) Complete Specification published 12 May 1976
(51) INT. CL.² C23C 9/00 11/00
(52) Index at acceptance
C7U 3 7C 9B1 9B3E 9B3F
C7F 1B2 1B3 1B4 2Z4 4K



(54) WEAR RESISTANT BORONIZED SURFACES AND BORONIZING METHODS

(71) We, HUGHES TOOL COMPANY of 5425 Polk Avenue, Houston, Texas 77023, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates in general to surface treatments of metals, particularly to those for steels requiring exceptional wear resistance under heavy loads such as those imposed upon earth boring drill bit bearings.

It has long been known that the surfaces of metals such as steel may be treated with a variety of elements or compositions that combine with the constituents of steel to produce hard wear resistant surfaces. One of the known prior art treatments is carburization. Another is boronizing.

The bearing surfaces of rotatable cutters in earth boring drill bits are commonly carburized, hardened and tempered to increase their wear resistance. Such surfaces sometimes have regions of soft anti-galling material such as silver or silver alloy, as disclosed in U.S. Patent No. 3,235,316. The mating surfaces of the opposing bearing shafts often include deposits of hard metal of cobalt based alloy of the "Stellite" series (Stellite is a Registered Trade Mark).

Boronizing of the bearing surfaces of earth boring drill bits has not heretofore been commercially successful, principally due to the brittle nature of the hard surfaces and their shallow depth.

This invention relates to the discovery that a wear resistant surface for steel such as a bearing surface in an earth boring drill bit may be constructed advantageously by a process that includes carburization, boronizing the resulting carburized surface, hardening in a manner to protect the boronized case from decarburizing, and then tempering. By carburizing and boronizing to the

requisite depths, hardening in a manner to produce a martensitic grain structure in the carburized case, and tempering to thereafter produce tempered martensite, a surface of extreme hardness results with a strong and tough supporting base. This base minimizes fracturing of the brittle boronized case since it is resistant to deformation and provides a satisfactory support for the boronized case.

Preferably the carburizing of the surface is performed to produce a carburized case depth of at least 0.076 cm, and the boronizing of said carburized case is performed to a depth of at least 0.0025 cm.

Fig. 1 is a fragmentary perspective view, partially in section, showing an earth boring drill bit and typical bearing which receives the metallurgical treatment described herein.

Fig. 2 is a cross-sectional view as seen looking along the lines II-II of Fig. 1.

The numeral 11 in the drawing designates an earth boring drill bit having a plurality of head sections or legs 13 joined by suitable means such as welding (not shown) and threaded at 15 for attachment to a supportive drill string member. One of the prior art lubrication and compensator systems 17, such as illustrated in Fig. 1, feeds lubricant through a passageway 19 and into a bearing region formed between a cantilevered shaft or pin 21 of the head section and a rotatable cutter 23 having teeth 25 for disintegrating earth. Suitable seal means 27 prevent the escape of lubricant from the bearing region, as explained in U.S. Patent No. 3,397,928.

The above mentioned bearings in an earth boring drill often include a primary friction region 29, an anti-friction ball bearing and cutter retainer region 31, and radial and thrust friction bearing regions designated respectively 33 and 35.

Fig. 2 shows in cross-section the canti-

levered bearing pin 21 and rotatable cutter 23. The cylindrical surface 35 of the bearing pin 21 receives the special treatment of the present invention, while the opposing surface of the rotatable cutter 23 receives a prior art treatment such as that described in Patent No. 3,235,315, preferably that using silver alloy. This patent teaches that improved friction bearings for earth boring drill bits result from the use of indentations filled with a soft anti-galling material such as silver or silver alloy 37 in a surface having a hardness and wear resistance comparable to carburized and hardened steel.

As previously stated this invention utilizes four primary method or process steps: carburizing, boronizing, hardening and tempering, each of which will be described separately by way of example. The initial step in the method of this invention requires carburization of a steel bearing surface such as the primary friction bearing region 29. One of the prior art carburization methods may be used. Gas carburizing is well known and is the preferred method. It is described on pp. 93-114 of Volume 2 of the 8th Edition of the Metals Handbook "Heat Treating, Cleaning and Finishing" (1964, American Society for Metals). An example of the gas carburizing of the bearing surfaces of a selectively copper plated rock bit head section made of A.I.S.I. 4815 steel is as follows:

Carburizing temperature: 927°C

Carburizing time: Nine hours at 927°C

Carburizing atmosphere: Generated endothermic gas enriched with methane to have a carbon potential of 1.35% carbon. A typical analysis of the carburizing gas (atmosphere) is as follows:

40% N_2
20% CO (CO_2 about 0.05%)
38% H_2
2% CH_4

This produces a carburized case depth of about 0.165 cm with carbon content at the surface about 1.00%.

Pack carburizing is another well known art that may be used. It is described on pp. 114-118 of Volume 2 of the Metals Handbook. An example of pack carburizing of the bearing surfaces of a rock bit head section made of A.I.S.I. 4815 steel is as follows:

Carburizing compound (packed around the surface to be carburized)
Charcoal, 90%; 3.32 to 1.17 mm size), energized with about 4% $BaCO_3$ and about 1.5% $CaCO_3$.

Carburizing temperature: 927°C

Carburizing time: Nine hours at 927°C

This produces a carburized case depth of about 0.165 cm with carbon content at the surface about 1.00%.

Liquid carburizing is another well known

art to the metals industry. It is described on pp. 133-145 of Volume 2 of the Metals Handbook. While not actually used for this invention, it is anticipated that nine hours at 927°C in a salt bath containing about 6-16% sodium cyanide and 30-55% barium chloride would produce a satisfactory carburized case to a depth of about 0.165 cm.

The second step of the method of this invention is boronizing of the previously carburized surfaces. Pack boronizing is the preferred technique and is a relatively new art.

An example of boronizing a carburized bearing surface of an A.I.S.I. 4815 steel head section is as follows:

Compound: Boronizing powder was packed around the carburized bearing surface. This powder was 90% finer than 0.104 mm, had 40-80% B_4C , 2-40% (graphite), 1-4% $KHCO_3$, with remainder up to 20% in impurities.

Boronizing temperature: 900°C (in a carburizing atmosphere).

Boronizing time: 5 hours at temperature in a furnace with a carbon potential of 1.00%. This produced a boronized case depth of about 0.010 cm. Longer boronizing times and/or higher boronizing temperatures can be used for deeper boronized case depth, but a 0.0025 to 0.025 cm deep boronized case has less tendency to crack or spall than a deeper case.

Gas boronizing is an alternate technique in the prior art. It is described in U.S. Patent No. 2,494,267, "Surface Hardening of Ferrous Metals", Schlesinger and Schaffer, Jan. 10, 1950. The method described utilizes gaseous diborane (B_2H_6) at about 700°C (1292°F).

Liquid boronizing is another prior art boronizing method. It is described in two papers: "Boronizing of Steel" by D. C. Durrill and Dr. Donald D. Allen, Magnetic Propulsion Systems, Inc. and "Boriding Steels for Wear Resistance" by Howard C. Fielder and Richard J. Sieraski, General Electric Co. (*Metal Progress*, Feb. 1971, pp. 101-107).

Neither gives the liquid salt bath composition, but the latter paper states that it contains fluorides of lithium, sodium, potassium and boron. Temperatures and times reported vary from 790°C - 900°C and from 15 minutes to 36 hours.

The third and fourth steps in the method of this invention are hardening and tempering of the carburized, boronized and cleaned steel surfaces.

The hardening and tempering of carburized steel is well known. The hardening, usually quenching in agitated oil, from a temperature of at least 755°C can be performed using one of several procedures, such

as the following two for carburized A.I.S.I. 4815 steel and produces a martensitic case:

(a) Single quench from a carburizing or reducing atmosphere and a temperature of 815°C.

(b) Double quench from a carburizing or reducing atmosphere and temperatures of respectively 843°C and 780°C.

Quenching from a carburizing or reducing atmosphere prevents decarburization or oxidation of the boronized case. Or a suitable coating such as copper plating may be used, in which case the quenching need not be from a reducing atmosphere. A suitable atmosphere is one similar to the previously explained methane enriched endothermic gas except slightly higher in CO₂ (about 0.4 to 0.8%) because of the lower temperatures.

The tempering temperature is usually low, 143°C - 265°C; preferably about 165°C for one hour, to toughen the carburized case without appreciably lowering its strength (hardness) to produce tempered martensite.

The above described procedures are utilized to produce a carburized foundation on the steel bearing pin 21 of at least 0.15 cm. The boronizing procedure produces a boronized case of at least 0.002 cm (average about 0.010 cm) with a surface hardness in a range of 900 to 2100 KHN. The hardening and tempering procedure develops a hardness in the carburized foundation in a range of 50 to 64 Rockwell "C" (550 to 800 KHN). When such a bearing pin is assembled with a rotatable cutter of the type shown in the drawing and described in United States Patent No. 3,235,315, overall bearing performance is much improved over that obtainable with a carburized bearing surface. Results indicate that such a surface performs comparably with much more expensive procedures such as when utilizing a deposit of hard metal of the cobalt based "Stellite" series in a groove on the bearing pin.

While the invention has been described in only a few of its forms it should be apparent to those skilled in the art that it is not so limited but is susceptible to various changes and modifications without departing from the scope thereof as defined by the appendant claims.

WHAT WE CLAIM IS:

1. The method of manufacturing steel articles requiring a strong and tough wear resistant surface, characterized in comprising the steps of:

carburizing said surface to produce a carburized case of selected depth;
boronizing said carburized case;
hardening said carburized case;
tempering said carburized case;
whereby the wear resistant boronized surface has a tough and strong supporting base

to sustain large loads and avoid brittle fracture.

2. The method according to claim 1, characterized in that the carburizing of said surface is performed to produce a carburized case depth of at least 0.076 cm; and that the boronizing of said carburized case is performed to a depth of at least 0.0025 cm.

3. The method according to claim 1 characterized in that the hardening of said carburized case is realized by quenching from a temperature to produce a martensitic grain structure and the tempering of said carburized case is realized to produce a tempered martensitic grain structure.

4. The method of manufacturing steel articles requiring a strong and tough wear resistant surface according to the claims 1-3 characterized in comprising the steps of:
carburizing said surface to a case depth of at least 0.076 cm;

boronizing said carburized case to a depth of at least 0.0025 cm;

quenching said carburized case from a temperature to produce a martensitic grain structure;

tempering said carburized case to produce a tempered martensitic grain structure;

whereby the wear resistant boronized surface has a tough and strong supporting base to sustain large loads and avoid brittle fracture.

5. The method according to claim 4 characterized in that the quenching of said carburized case is performed from a temperature of at least 755°C to produce a martensitic grain structure; and that tempering of said carburized case is performed from a temperature within a range of 143°C to 265°C for about one hour to produce a tempered martensitic grain structure.

6. An earth boring drill bit having at least one rotatable cutter supported on a steel bearing pin, submitted to the treatment according to the claims 1-5 characterized in that it comprises:

a carburized friction bearing surface formed on said steel bearing pin;

a boronized surface formed on said carburized bearing surface;

said carburized surface being hardened and tempered by heat treatment;

whereby the wear resistant boronized surface has a tough and strong supporting base to sustain large loads imposed by a mating friction bearing in said rotatable cutter and avoid brittle fracture.

7. An earth boring drill bit according to claim 6 characterized in that the friction bearing surface formed on said steel bearing pin has a carburized case of a depth of at least 0.076 cm and the boronized surface formed on said carburized case has a depth of at least 0.0025 cm.

8. An earth boring drill bit according to

as the following two for carburized A.I.S.I. 4815 steel and produces a martensitic case:

(a) Single quench from a carburizing or reducing atmosphere and a temperature of 815°C.

(b) Double quench from a carburizing or reducing atmosphere and temperatures of respectively 843°C and 780°C.

Quenching from a carburizing or reducing atmosphere prevents decarburization or oxidation of the boronized case. Or a suitable coating such as copper plating may be used, in which case the quenching need not be from a reducing atmosphere. A suitable atmosphere is one similar to the previously explained methane enriched endothermic gas except slightly higher in CO₂ (about 0.4 to 0.8%) because of the lower temperatures.

The tempering temperature is usually low, 143°C-265°C; preferably about 165°C for one hour, to toughen the carburized case without appreciably lowering its strength (hardness) to produce tempered martensite.

The above described procedures are utilized to produce a carburized foundation on the steel bearing pin 21 of at least 0.15 cm. The boronizing procedure produces a boronized case of at least 0.002 cm (average about 0.010 cm) with a surface hardness in a range of 900 to 2100 KHN. The hardening and tempering procedure develops a hardness in the carburized foundation in a range of 50 to 64 Rockwell "C" (550 to 800 KHN). When such a bearing pin is assembled with a rotatable cutter of the type shown in the drawing and described in United States Patent No. 3,235,315, overall bearing performance is much improved over that obtainable with a carburized bearing surface. Results indicate that such a surface performs comparably with much more expensive procedures such as when utilizing a deposit of hard metal of the cobalt based "Stellite" series in a groove on the bearing pin.

While the invention has been described in only a few of its forms it should be apparent to those skilled in the art that it is not so limited but is susceptible to various changes and modifications without departing from the scope thereof as defined by the appendant claims.

WHAT WE CLAIM IS:

1. The method of manufacturing steel articles requiring a strong and tough wear resistant surface, characterized in comprising the steps of:

carburizing said surface to produce a carburized case of selected depth;
boronizing said carburized case;
hardening said carburized case;
tempering said carburized case;
whereby the wear resistant boronized surface has a tough and strong supporting base

to sustain large loads and avoid brittle fracture.

2. The method according to claim 1, characterized in that the carburizing of said surface is performed to produce a carburized case depth of at least 0.076 cm; and that the boronizing of said carburized case is performed to a depth of at least 0.0025 cm.

3. The method according to claim 1 characterized in that the hardening of said carburized case is realized by quenching from a temperature to produce a martensitic grain structure and the tempering of said carburized case is realized to produce a tempered martensitic grain structure.

4. The method of manufacturing steel articles requiring a strong and tough wear resistant surface according to the claims 1-3 characterized in comprising the steps of:
carburizing said surface to a case depth of at least 0.076 cm;

boronizing said carburized case to a depth of at least 0.0025 cm;

quenching said carburized case from a temperature to produce a martensitic grain structure;

tempering said carburized case to produce a tempered martensitic grain structure;

whereby the wear resistant boronized surface has a tough and strong supporting base to sustain large loads and avoid brittle fracture.

5. The method according to claim 4 characterized in that the quenching of said carburized case is performed from a temperature of at least 755°C to produce a martensitic grain structure; and that tempering of said carburized case is performed from a temperature within a range of 143°C to 265°C for about one hour to produce a tempered martensitic grain structure.

6. An earth boring drill bit having at least one rotatable cutter supported on a steel bearing pin, submitted to the treatment according to the claims 1-5 characterized in that it comprises:

a carburized friction bearing surface formed on said steel bearing pin;

a boronized surface formed on said carburized bearing surface;

said carburized surface being hardened and tempered by heat treatment;

whereby the wear resistant boronized surface has a tough and strong supporting base to sustain large loads imposed by a mating friction bearing in said rotatable cutter and avoid brittle fracture.

7. An earth boring drill bit according to claim 6 characterized in that the friction bearing surface formed on said steel bearing pin has a carburized case of a depth of at least 0.076 cm and the boronized surface formed on said carburized case has a depth of at least 0.0025 cm.

8. An earth boring drill bit according to



- claims 6 or 7 characterized in that the carburized case is quenched from a temperature to produce a martensitic grain structure and that said carburized case is
- 5 tempered to produce a tempered martensitic grain structure.
9. An earth boring drill bit according to claims 6 and 7 characterized in that the carburized case is quenched from a temperature
- 10 of at least 755°C to produce a martensitic grain structure and that the carburized case is tempered from a temperature within a range of 143°C to 265°C for about
- 15 one hour to produce a tempered martensitic grain structure.
10. The method of manufacturing the earth boring drill bits having at least one rotatable cutter supported on a steel bearing pin, according to claims 6-9 characterized
- 20 in comprising the steps of:
forming a friction bearing surface on said bearing pin to produce a carburized case of selected depth;
boronizing said carburized case;
25 hardening said carburized case;
tempering said carburized case;
whereby the wear resistant boronized surface has a tough and strong supporting base to sustain large loads and avoid brittle
- 30 fracture.
11. The method according to claim 10, characterized in that said carburizing is to a depth of at least 0.076 cm and said boronizing is to a depth of at least 0.0025 cm.
- 35 12. The method of claim 11 characterized in that said hardening is by quenching from a temperature of at least 755°C, and said tempering is from a temperature within a range of 143°C to 265°C for about
- 40 one hour.
13. An article of manufacture of steel submitted to the treatment of claims 1-5 characterized in comprising a carburized wear resistant steel surface;
- a boronized surface formed on said carburized steel surface;
- said carburized surface being quenched from a temperature sufficient to produce a martensitic grain structure, thereafter tempered;
- 50 whereby the wear resistant boronized surface has a tough and strong supporting base to sustain large loads and avoid brittle fracture.
14. The article of claim 13 characterized
- 55 in that said carburized surface is carburized to a depth of at least 0.076 cm and said boronized surface has a depth of at least 0.0025 cm.
15. The article of claim 14 characterized
- 60 in that said quenching temperature is at least 755°C and the tempering is from a temperature within a range of 143°C to 265°C for about one hour whereby a tempered martensitic grain structure occurs in
- 65 the carburized case.
16. The article of claim 14 wherein the hardness of the surface of the carburized surface, after quenching and tempering is within a range of 550 to 800 KHN.
- 70 17. The article of claim 17 wherein the hardness of the boronized surface is within a range of 900 to 2100 KHN.
18. The method of manufacturing steel articles according to claim 1 and as hereinbefore described with reference to the accompanying drawings.
- 75 19. An earth boring drill bit according to claim 6 and as hereinbefore described with reference to the accompanying drawings.
- 80

GERALD CARTER & COMPANY
Chartered Patent Agents
11 Aklia Court
Shepherds Hill
London, N.6.
Agents for the Applicants

