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[11] 3,842,921
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[54] BORONIZED DRILL BIT CUTTERS

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[51] Int. Cl. E21b 13/00
[58] Field of Search 148/16.5, 19, 31, 5, 30, 148/15.5; 308/8.2; 175/374, 409

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[57] ABSTRACT

Disclosed herein is a cutter for an earth boring drill bit having selected exterior surface areas that are carburized, boronized, quenched and tempered for extreme surface hardness, with a strong, tough supporting base that resists deformation and minimizes fracturing of the brittle boronized case. This produces a wear resistant case which may be used as an improved substitute for hardfacing.

7 Claims, 4 Drawing Figures

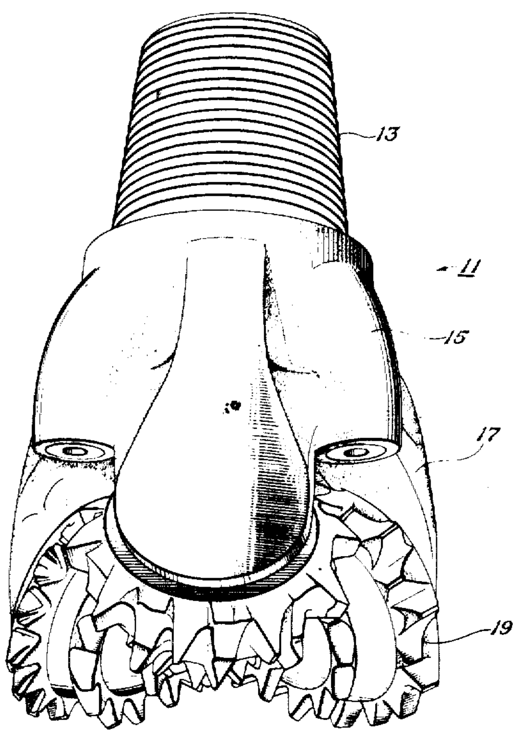


Fig. 1

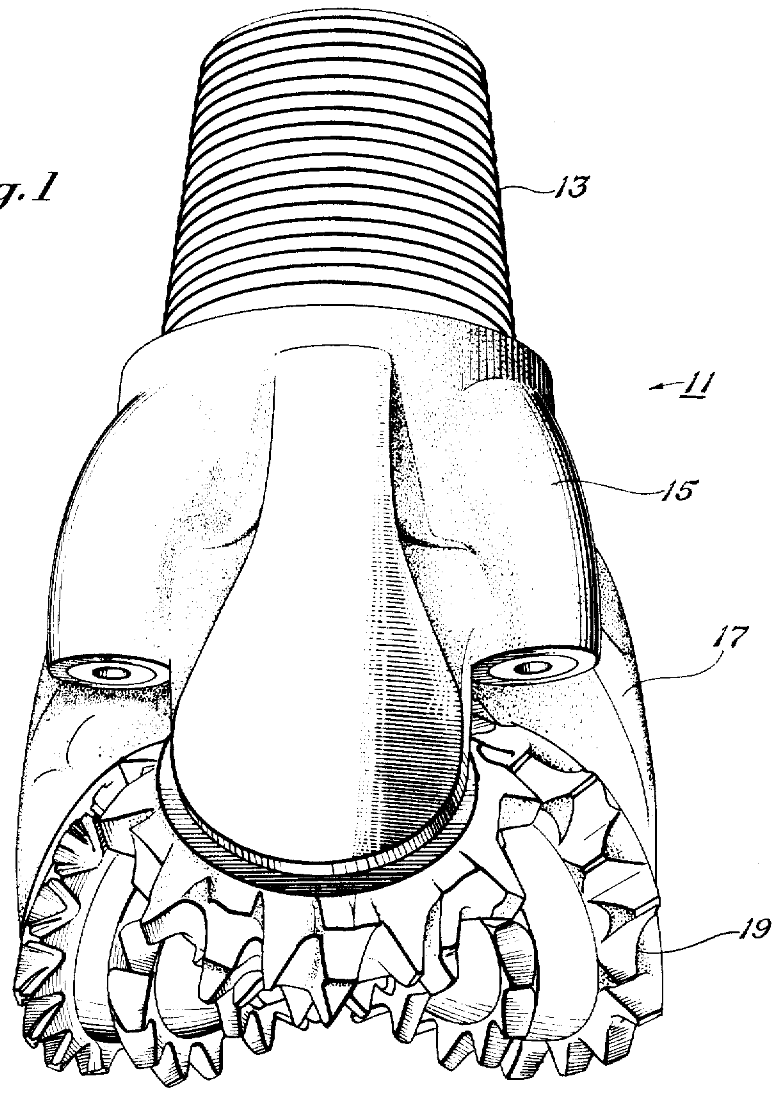
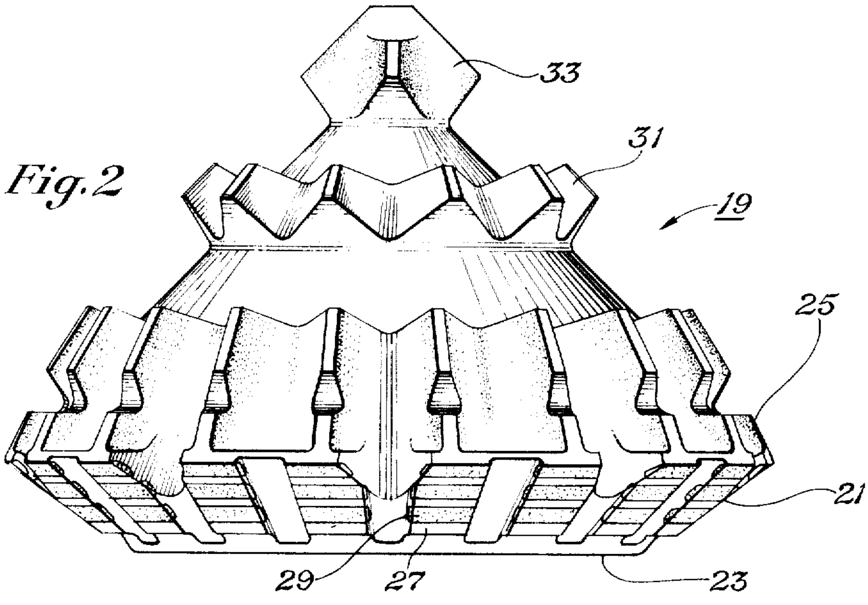


Fig. 2



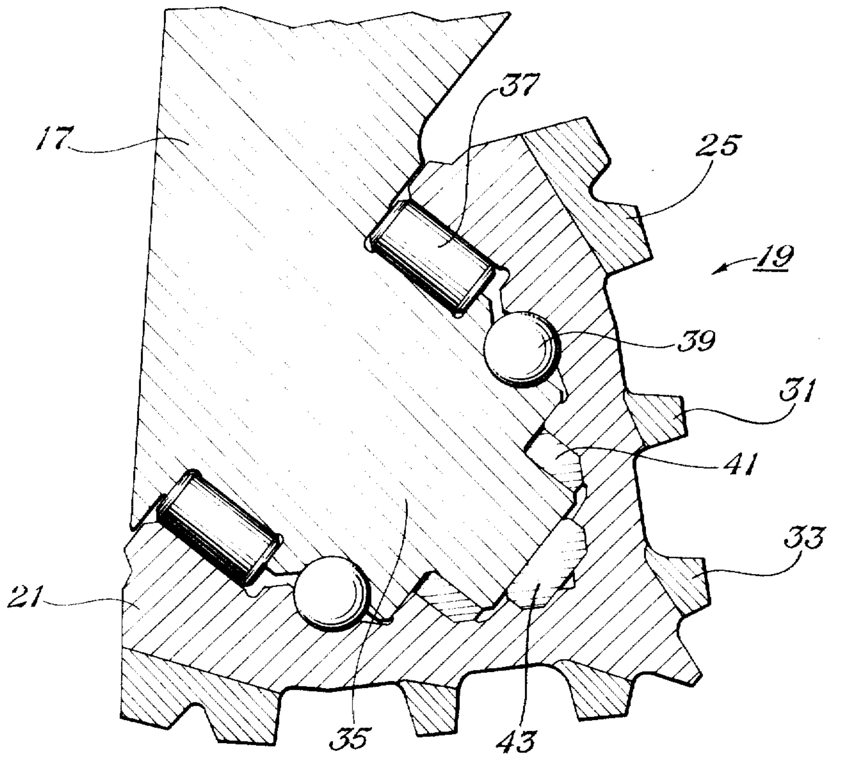


Fig.3

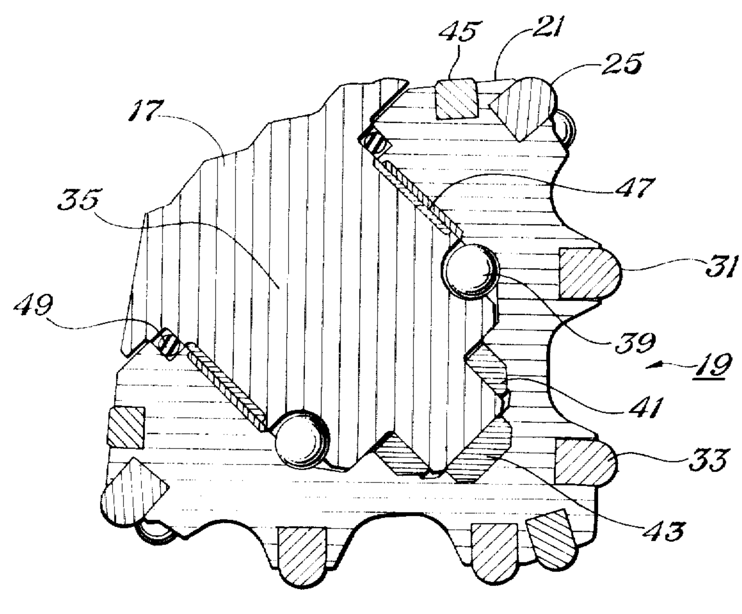


Fig.4

BORONIZED DRILL BIT CUTTERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to earth boring drill bits, particularly to metallurgical treatments that increase the wear resistance and hence the life of cutters and teeth exposed to abrasive wear.

2. Description of the Prior Art

The common prior art method for retarding the abrasive wear of earth disintegrating teeth and cutters used in earth boring drill bits is the application of hardfacing to selected surfaces. A typical hard-facing used on teeth and cutters is a composite material consisting essentially of an alloy steel matrix in which are dispersed particles of sintered tungsten carbide. This composite material is applied by a welding process by which a steel tube filled with tungsten carbide particles and ferroalloys is heated to a temperature sufficient to melt the steel tube and to fuse the composite to the selected surfaces. As a result, a strong metallugrical bond is created. Unfortunately, melting the metal of the tooth causes a weakening of the tooth, particularly under impact loads. Thus, there exists a long standing problem of premature tooth breakage when heavy loads are applied to hardfaced teeth during earth drilling. The subsequently described invention is directed primarily to a solution to this problem.

Previously, it was thought that boronizing teeth and cutters would improve their abrasive wear resistance, but the extremely brittle nature of the resulting boronized surfaces led to the formation of detrimental cracks. As a consequence, the problem became how one could obtain the advantages of the extremely hard and wear resistant boronized surface in a manner compatible with the other metallurgical requirements of the teeth and cutters.

SUMMARY OF THE INVENTION

This invention relates to the discovery that an exceptionally wear resistant case may be produced on surfaces such as teeth and cutters of an earth boring drill bit by carburizing these surfaces, boronizing the resulting carburized surfaces, 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 martensitic 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. The resulting surface is sufficiently abrasion resistant to replace the hardfacing of the prior art. Tooth failure due to weakening as a result of the prior art hardfacing operation is thereby minimized.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of an earth boring drill bit having in this instance cutters and teeth that receive the metallurgical treatment described herein.

FIG. 2 is a side elevation view of another type cutter used in an earth boring drill bit, such cutter having a gage surface, heel row, intermediate row and inner row of teeth to dislodge cuttings from a borehole bottom during drilling.

FIG. 3 is a fragmentary side elevation view, partially in section, showing a rotatable cutter mounted on suitable bearing means extending in cantilevered fashion from a drill bit leg or head section.

FIG. 4 is a fragmentary side elevation view, partially in section, of an alternate form of cutter and teeth used in drilling, such cutter teeth having the metallurgical treatment described herein.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The numeral **11** in the drawing designates a typical earth boring drill bit having a threaded shank **13** for attachment to a drill string member, nozzle means **15** for directing a flow of fluid toward a borehole bottom, and in this instance three depending legs or head sections **17** that each support a toothed, rotatable cutter **19**.

In FIG. **2** is shown an alternate form of cutter which has the typical conical basic configuration, including a conical gage surface **21** extedning from the cone back face **23** to the heel row teeth **25**. The gage surface is formed with alternate areas of steel ribs **27** and bands **29** of a composite hardfacing material consisting essentially of an alloy steel matrix and particles of sintered or cemented tungsten carbide. This particular cutter has an intermediate row **31** of teeth and an extreme inner row or spear point **33**.

A cutter such as that shown in FIG. **2** is generally mounted on a leg or head section **17** (see FIG. **3**) with a cantilevered shaft or bearing pin **35** that forms a bearing means on the interior of the cutter. The particular bearing means illustrated is primarily of the antifriction type, having a row of roller bearings **37**, a row of ball bearings **39**, and two friction bearing means that utilize a bushing **41** and a thrust button **43**.

In FIG. **4** is shown an alternate form of rotatable cutter and bearing configuration in which the cone **19** has its heel row **25**, intermediate row **31**, and inner row **33** formed with wear resistant inserts or compacts, preferably constructed in the prior art of cemented tungsten carbide with a cobalt binder, and inserted with interference fit in matching holes drilled into the cone exterior. The gage surface **21** has a row of gage packs **45** substituted for the hardfacing **29** used on the FIG. **2** type cone configuration. The head section **17** and its cantilevered bearing pin **35** have a friction bearing **47** in place of the rollers **37** in the FIG. 3 embodiment, and in addition, have a row of ball bearings **39**, and friction bearing means utilizing the bushing **41** and thrust button **43**. In this instance a seal means such as an o-ring **49** is placed in suitable groove means between the bearing pin **35** and cutter **19** to retain a lubricant within the bearing region.

This invention is best practiced through utilization of four method steps: carburizing, boronizing, hardening and tempering, each of which will be described separately by way of example. The initial step in the method requires carburizing the rotatable cutter or selected areas. One of the prior art carburizing methods may be used. Gas carburizing is a well known art 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 a rotatable cutter made of A.I.S.I. 4815 steel is as follows:

Carburizing temperature: 1,700° F.

Carburizing time: Nineteen hours at 1,700° F.

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

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

This produces a carburized case depth of about 0.090 inch with carbon content at the surface about 1.00 percent.

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 a cutter made of A.I.S.I. 4815 steel is as follows: Carburizing compound (in which cutter is packed): Charcoal, 90 percent (6 to 14 mesh size), energized with about 4 percent $BaCO_3$ and about 1.5 percent $CaCO_3$.

Carburizing temperature: 1,700° F.

Carburizing time: Nineteen hours at 1,700° F.

This produces a carburized case depth of about 0.090 inch with carbon content at the surface about 1.00 percent.

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 nineteen hours at 1,700° F. in a salt bath containing about 6 – 16 percent sodium cyanide and 30–55 percent barium chloride would produce a satisfactory carburized case to a depth of about 0.090 inch.

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

An example of boronizing the exterior surface of a carburized A.I.S.I. 4815 steel cutter is as follows: Compound: Boronizing powder was packed around the carburized bearing exterior surface. This powder was 90 percent finer than 150 mesh, had 40–80 percent B_4C, 2–40 percent graphite, 1–4 percent $KHCO_3$, with remainder up to 20 percent impurities. Boronizing temperature: 1,650° F. in a carburizing atmosphere. Boronizing time: 8 hours at temperature in a furnace with a carbon potential of 1.00 percent. This produced a boronized case depth of about 0.005 inch. Longer boronizing times and/or higher boronizing temperatures can be used for deeper boronized case depth, but a 0.001 to 0.010 inch 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. Pat. 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 (1,292° 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 flourides of lithium, sodium, potassium, and boron. Temperatures and times reported vary from 1,450° – 1,650° F. 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 a well known art. The hardening, usually quenching in agitated oil, from a temperature of at least 1,390° F., can be performed using one of the following procedures for carburized A.I.S.I. 4815 steel to produce a substantially martensitic case:

a. Double quench from a carburizing or reducing atmosphere and temperatures of respectively 1,550° and 1,435° F. is preferred.

b. Single quench from a carburizing or reducing atmosphere and a temperature of 1,500° F.

De-carburization or oxidation of the boronized case may be prevented by using a carburizing or reducing atmosphere or by a coating such as copper plating. A suitable atmosphere is similar to the previously explained methane enriched endothermic gas except slightly higher in CO_2 (about 0.4 to 0.8 percent) because of the lower temperatures.

The tempering temperature is usually low, 290° – 510° F., preferably about 330° F. for one hour, to toughen the carburized case without appreciably lowering its strength (hardness) to produce tempered martensite.

A satisfactory method for boronizing drill bit cutters and teeth produces a carburized foundation on the steel cutter of at least 0.030 inch. In addition a boronized case of at least 0.001 inch is produced (average about 0.005 inch) with a surface hardness in a range of about 900 to 2,100 KHN. The hardening and tempering procedure develops a hardness in the carburized foundation in the range of about 50 to 64 Rockwell C (550 to 800 KHN).

Three rotatable cutters treated in accordance with the foregoing first examples were assembled with head sections to form an earth boring drill bit, which was secured during operation to the lower end of a drill string member by threads **13** (see FIG. **1**). The drill string was then lowered and rotated to urge the cutter teeth into the earth's formations. The bits of the present invention in actual drilling exhibited resistance to abrasive wear comparable to that obtained with the prior art hard-faced teeth. In addition, there was a significant reduction of tooth breakage in most instances since the method of this invention did not detrimentally affect the strength of the teeth. Thus, even though the extremely hard boronized case was relatively shallow, the carburized, hardened and tempered supporting base was sufficiently resistant to deformation to avoid fracture of the boronized case. Simultaneously, the boronized case had sufficient abrasion resistance to retard wear over the normal life span of the drill bit.

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 spirit thereof. The entire exterior surface of a cutter such as that shown in FIG. **3** may receive the treatment of the invention. On the other hand individual teeth such as the inserts shown in FIG. **4** may be treated according to the invention and substituted for the prior art inserts. Or the cutter surfaces surrounding prior art tungsten carbide inserts may be treated according to the invention to prevent cone surface erosion between the inserts. In summary the invention will find many applications in which wear resistance, strength and durability are required.

We claim:

1. In an earth boring drill bit, an improved rotatable cutter comprising:

a carburized case on the cutter exterior;

a boronized case on said carburized case;

said carburized case being heat treated such that the boronized case has a strong and tough supporting base that resists deformation.

2. The apparatus of claim **1** wherein the carburized case has a depth of at least 0.030 inch and said boronized layer has a depth of at least 0.001 inch.

3. The apparatus of claim **1** wherein the carburized case has a hardness comparable to tempered martensite.

4. In an earth boring drill bit, an improved rotatable cutter comprising:

a carburized case on selected earth disintegrating teeth of said cutter;

a boronized case over selected carburized teeth;

said carburized case being hardened to produce a hardness comparable to that of tempered martensite;

whereby said teeth have an extremely hard and wear resistant boronized case over a deformation resistant carburized case.

5. In an earth boring drill bit, an improved rotatable cutter comprising:

a carburized case of at least 0.030 inch on selected areas of said cutter;

a boronized case of at least 0.001 inch over the carburized case;

said carburized case being hardened to produce a hardness comparable to that of tempered martensite;

whereby said teeth have an extremely hard and wear resistant boronized case over a deformation resistant carburized case.

6. The apparatus of claim **5** wherein the hardness of the surface of the carburized case is within a range of about 550 to 800 KHN.

7. The apparatus of claim **6** wherein the surface hardness of the boronized case is within a range of about 900 to 2,100 KHN.

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