# United States Patent [19]

**Anderson et al.**

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[54] **NITRIDED BORON STEEL**


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**Related U.S. Application Data**

[63] Continuation of Ser. No. 252,739, May 12, 1972, abandoned.

[52] **U.S. Cl.** ..... **148/16.6**; 75/123 B; 75/123 J; 148/31.5

[51] **Int. Cl.**... **C22c 39/50**; C23c 11/16; C22c 39/54

[58] **Field of Search** ..... 75/123 B, 123 J; 148/16.6, 148/31.5, 143



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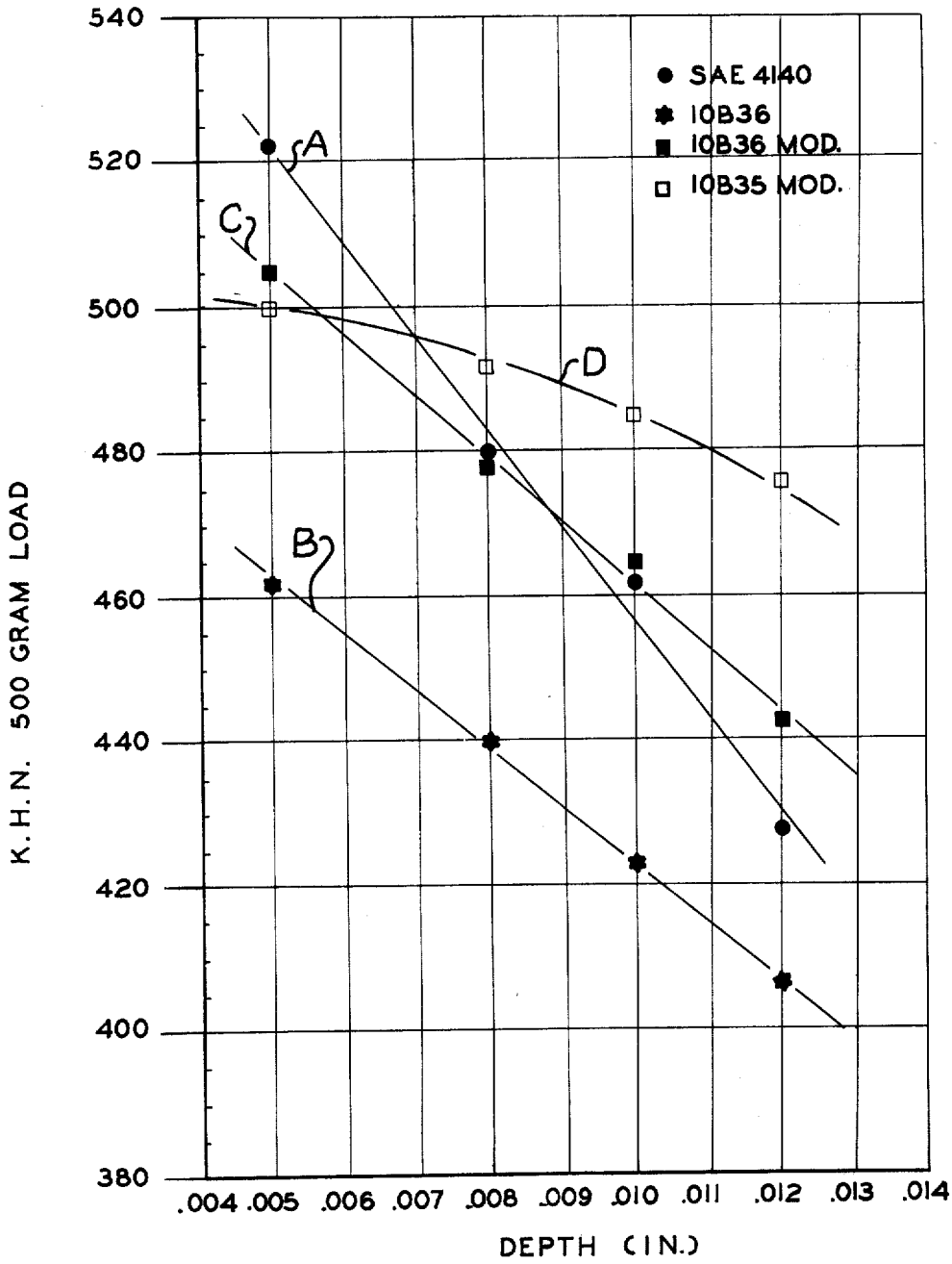
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[57] **ABSTRACT**

A method of economically producing steel parts having high case hardness and commensurate core properties, the parts being formed from low carbon steel containing about 0.25 to 0.50 percent of carbon, about 0.80 to 1.60 percent of manganese, about 0.40 maximum percent of silicon, about 0.0003 to 0.005 percent of boron, up to approximately 0.1 percent of a suitable nitriding agent such as vanadium, titanium tungsten, aluminum, zirconium, columbium, chromium or molybdenum, balance essentially iron, the boron and nitriding agent being in an uncombined or atomic form, the parts being hardened to develop desirable core properties and then being nitrided to develop case hardness.


**2 Claims, 1 Drawing Figure**


540
520
500
480
460
440
420
400
380
K.H.N. 500 GRAM LOAD
.004 .005 .006 .007 .008 .009 .010 .011 .012 .013 .014
DEPTH (IN.)
SAE 4140
10B36
10B36 MOD.
10B35 MOD.
A
B
C
D

# NITRIDED BORON STEEL

This is a continuation of application Ser. No. 252,739, filed May 12, 1972, now abandoned.

## BACKGROUND OF THE INVENTION

The present invention relates to a process for producing nitrided steel and more particularly to such a process wherein a steel of economical composition is case hardened by conventional nitriding techniques.

The nitriding process by which the surface or case hardness of steel can be substantially increased is well known and involves the formation of hard wear resistance nitrogen compounds at the surface of the steel. In conventional gas nitriding, the steel parts are heated to a temperature range of approximately 925° F to 1000° F, for example, and maintained at that temperature for an extended period of time while ammonia gas is circulated around the parts. The ammonia gas is partially dissociated at the elevated temperature so that nascent or free nitrogen is released at the surface of the steel parts and absorbed therein. A portion of the nitrogen diffuses toward the center of the parts to form nitrides and provide desirable depth hardness. One of the advantages of the nitriding process is that the temperatures are relatively low as compared for example to carburization or conventional hardening processes such as heating the steel parts above an upper critical temperature and quenching. Thus, the nitriding process results in minimized distortion of the parts while also minimizing stress development. At the same time, the nitriding process develops a very hard and wear-resistant case upon the parts. Because of the high hardness developed in the case, it is also necessary to properly condition the core of the parts to provide adequate support for the case. Desirable core properties for nitrided parts include core toughness, beam strength and depth hardness.

One of the principle disadvantages of the nitriding process is that expensive alloy steels such as SAE 4140 H alloy steel have commonly been required to permit the development of suitable properties within the case and core of the nitrided steel parts.

## SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a method for economically producing nitrided steel parts having satisfactory physical properties in both the case and core. In keeping with this object, it has been discovered that boron grade steel or low carbon steels containing boron either alone or in combination with conventional nitride forming elements responds to nitriding treatment to develop desirable case hardening. Accordingly, the present invention contemplates a process for nitriding steel parts formed from steel containing approximately 0.25 to 0.50 percent of carbon, approximately 0.80 to 1.60 percent of manganese, approximately 0.0003 to 0.005 percent of boron, no more than approximately 1 percent of conventional alloying agents and up to approximately 0.1 percent of a nitriding agent. More particularyly, these percentages for the boron and nitriding agent are maintained in the uncombined or atomic form during conventional hardening to develop core properties and during subsequent nitriding to develop high case hardness.

It is also an object of the present invention to provide steel parts as a product of the process described above.



It is well known that boron in amounts less than 0.005 percent can be substituted for much greater quantities of critical and expensive alloying agents in steel to achieve hardenability in high temperature quenching operation. However, it has now been discovered that low carbon steels containing boron either alone or in combination with other conventional nitriding agents are responsive to nitriding conditions to develop very satisfactory case properties. It has apparently been previously believed that when nitrogen interacts with boron, it tends to reduce or nullify the effect of boron on hardenability.

Boron is known to have affinity for nitrogen. Upon combining with other elements such as nitrogen, the boron is made ineffective for conventional hardening, austenization and quenching. The ability of uncombined or atomic boron to improve conventional hardenability is not believed to be completely understood nor is the mechanism by which boron permits effective nitriding according to the present invention completely understood. It is believed that the uncombined boron assists in case formation by combining with nitrogen to form hard boron nitride particles. Distinct differences in grain boundary precipitates further tend to indicate the presence of boron nitride after nitriding.

In accordance with the present invention, it has further been discovered that not only does the presence of boron increase the nitriding response of low carbon steel but that the combination of boron with other conventional nitriding agents provides a greatly increased nitriding response indicating a synergistic effect from the combination of boron with the other nitriding agent. The other nitriding agent may preferably be present in quantities up to approximately 0.1 percent and may be selected from conventional nitriding agents such as vanadium, aluminum, titanium, chromium, molybdenum, tungsten, zirconium or columbium.

It is possible that the boron content may be greater than the range indicated above for further increased hardness. Also, the contribution of boron to nitriding response will be present in steels having greater amounts of alloying agents than indicated above. The above composition is intended to illustrate the economic possibility of nitriding a low carbon or non-alloy steel and developing satisfactory case and core properties.

Additional objects and advantages of the present invention are made apparent in the following description having reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWING

The drawing is a graphical representation of the case hardness for various nitrided steels, certain of which are produced in accordance with the present invention.

In producing nitrided steel parts according to the present invention, the parts are formed from steel containing approximately 0.25 to 0.50 percent carbon indicating a general classification of low carbon steel. The steel also contains approximately 0.80 to 1.60 percent of manganese. Normal impurities are also contemplated such as silicon to a maximum of 0.40 percent, as well as 0.050 maximum percent of sulfur and 0.050 maximum percent of phosphorus. To provide a nitriding response, the steel also contains 0.0003 to 0.005 percent of atomic or uncombined boron as well as up to approximately 0.10 percent of a conventional nitriding agent such as vanadium, aluminum, titanium, chro-

mium, molybdenum, tungsten, zirconium or olumbium also in an atomic or uncombined form. An exemplary composition is set forth below containing both boron and vanadium and it is to be noted that other nitriding agents from the above list could be substituted for the vanadium to provide a generally equivalent nitriding response.

The above composition also suggests the use of low carbon steels having residual alloy content within the present invention. Steels produced for example, in cold melt shops using steel scrap for charge, often contain substantial amounts of residual alloys and may be satisfactory for use within the present invention. However, even with the presence of certain residual alloys, some of which may also be nitriding agents from the list noted above, any nitriding agent must be present in its atomic or uncombined form to contribute to the nitriding response of the steel. Accordingly, the total content of certain nitriding agents may be greater than the percentage noted above if both the combined and uncombined forms of those agents are considered.

As contemplated by the present invention, the steel parts are preliminarily hardened to develop desired core properties of toughness, beam strength and depth hardness. For example, the parts may be carburized, quenched and tempered in accordance with conventional techniques for developing such core properties in parts to be subsequently nitrided. However, this step illustrates an additional advantage of the present invention in that the uncombined boron also increases hardenability of the steel during this initial step. Accordingly, it may be seen that the uncombined boron is effective not only during the nitriding process but also during a preliminary hardening treatment to contribute to properties of the core, particularly depth hardness.

Following initial hardening, the steel parts are then nitrided such as in the conventional gas nitriding process described above. However, it should be noted that other nitriding techniques may also be used in the present invention. Liquid salt nitriding, for example, may be employed in certain applications instead of gas nitriding.

The graph illustrates the Knoop hardness at various depths through the case for nitrided steel parts. Hardness to a depth of approximately 0.012 inches was recorded since this approaches the maximum depth of case formation in conventional nitriding processes.

In the graph, four steels are indicated respectively by the letters A, B, C and D. The compositions of these various steels are as follows:

| | | |
|---|---|---|
| (A) | SAE 4140M Alloy Steel | |
| | C | 0.37 – 0.44 |
| | Mn | 0.65 – 1.10 |
| | P | 0.035 max. |
| | S | 0.040 max. |
| | Si | 0.20 – 0.35 |
| | Cr | 0.75 – 1.20 |
| | Mo | 0.15 – 0.25 |
| (B) | SAE 10B36 Boron Steel | |
| | C | 0.30 – 0.37 |
| | Mn | 1.25 – 1.55 |
| | P | 0.040 max. |
| | S | 0.050 max. |
| | Si | 0.15 – 0.40 |
| | B | 0.0005 – 0.003 |
| (C) | SAE 10P36 Modified Boron-Vanadium Steel | |
| | C | 0.30 – 0.37 |
| | Mn | 1.25 – 1.55 |
| | P | 0.040 max. |
| | S | 0.050 max. |

-Continued

| | | |
|---|---|---|
| (A) | SAE 4140M Alloy Steel | |
| | Si | 0.15 – 0.40 |
| | B | 0.0005 – 0.003 |
| | V | 0.03 – 0.05 |
| (D) | SAE 10B35 Modified Boron-Vanadium Steel | |
| | C | 0.32 – 0.39 |
| | Mn | 0.60 min. |
| | P | 0.040 max. |
| | S | 0.050 max. |
| | Si | 0.15 – 0.30 (0.40 permitted) |
| | B | 0.0005 – 0.003 |
| | V | 0.03 – 0.05 |

The alloy steel A is shown in the drawing for purposes of comparison and clearly indicates the high hardness achieved through the nitriding of low carbon steels containing boron either alone or in combination with a nitriding agent such as vanadium. It is, of course, to be noted that other nitriding agents may be substituted for vanadium with generally an equivalent nitriding response. The B composition steel indicates the response of boron to nitriding and the compositions C and D indicate the improved response of low carbon steel containing both boron and a nitriding agent such as vanadium. The case characteristics of the composition D steel appears to strongly suggest a synergistic effect between the boron and vanadium in relation to the nitriding response of the steel.

What is claimed is:

1. A method of economically producing steel parts having high case hardness and commensurate core properties, comprising the steps of forming the steel parts from steel consisting of about 0.25 to 0.50 percent of carbon, about 0.8 to 1.60 percent of manganese, normal impurities, about 0.0003 to 0.005 percent of boron, approximately 0.03 to 0.05 percent vanadium as a nitriding agent, and the balance iron, the boron and vanadium being present in uncombined form, preliminarily hardening the parts to develop core toughness, beam strength and depth hardness, and nitriding the steel parts to form a case having a minimum Knoop hardness of approximately 400 to a depth of approximately 0.012 inches.

2. Steel parts having high case hardness and commensurate core properties of core toughness, beam strength and depth hardness, the parts being produced by the steps of forming the parts from steel consisting of approximately 0.25 to 0.50 percent carbon, approximately 0.80 to 1.60 percent of manganese, normal impurities, approximately 0.0003 to 0.005 percent of boron, approximately 0.03 to 0.05 percent vanadium as a nitriding agent and the balance iron, the boron and vanadium being present in uncombined form, the parts being initially hardened to develop desirable core properties and subsequently nitrided to develop a minimum Knoop case hardness of approximately 400 to a depth of approximately 0.012 inches.

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