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(54) **CARBURIZED ALLOY STEEL HAVING  
SUPERIOR DURABILITY AND METHOD OF  
MANUFACTURING THE SAME**

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(57) **ABSTRACT**

A carburized alloy steel including, based on the total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), and a balance of iron (Fe). A method of manufacturing the same is also provided.

**CARBURIZED ALLOY STEEL HAVING  
SUPERIOR DURABILITY AND METHOD OF  
MANUFACTURING THE SAME**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

**[0001]** This application claims the benefit of priority under 35 U.S.C. §119 to Korean Patent Application No. 10-2014-0175183, filed on Dec. 8, 2014, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

**[0002]** The present invention relates to a carburized alloy steel having superior durability and a method of manufacturing the same, and more particularly, to a carburized alloy steel having an appropriate constitutional component and content so as to effectively cause carburizing on a surface of the alloy steel and thus improve hardness, strength, toughness, fatigue strength, a fatigue life, and the like, and a method of manufacturing the same.

BACKGROUND

**[0003]** In vehicle industries, various environmentally-friendly vehicles have been developed with an object of reducing a discharge amount of carbon dioxide to 95 g/km that is a level of 27% of a current amount thereof until 2021 based on European regulations. Further, vehicle makers strive to develop a technology to downsize and improve fuel economy in order to meet 54.5 mpg (23.2 km/l) which is a regulation value of corporate average fuel economy (CAFE) in the USA by 2025.

**[0004]** Particularly, a high performance and high efficiency technology of engines and transmissions for maximizing fuel economy of vehicles has been developed, and this technology includes an increase in number of gears, a novel concept driveaway device, a high efficiency two-pump system, a fusion hybrid technology, technologies relating to an automatic/manual fusion transmission and a hybrid transmission, and the like.

**[0005]** An alloy steel used in the technology relating to the transmission is used in carriers, gears, shafts, synchronizer hubs, and the like of the transmission. A use ratio of the alloy steel is currently about 58 to 62 wt % based on the total weight of the transmission. Particularly, in the gears of the transmission and the like, development of downsized high strength and highly durable materials with reduced weight is required.

**[0006]** Generally, the gears of a vehicle transmission are parts performing a role of directly transferring engine power to a differential system and effectively transferring rotation or power between two or more shafts so that engine power is attuned to a driving state of the vehicle. Since bending stress and contact stress are simultaneously received, high physical properties such as hardness, strength, toughness, fatigue strength, and a fatigue life are required.

**[0007]** As an alternative of the aforementioned requirement, currently, a carburized steel such as SCM820PRH including 0.17 to 0.23 wt % of carbon (C), 0.5 to 0.7 wt % of silicon (Si), 0.45 to 0.75 wt % of manganese (Mn), 1.95 to 2.25 wt % of chromium (Cr), 0.015 to 0.035 wt % of molybdenum (Mo), 0.0015 wt % of oxygen (O<sub>2</sub>), and the like is used.

**[0008]** However, in the carburized steel, fatigue failure such as tooth breakage easily occurs due to a lack of bending fatigue strength and the like and fatigue damage such as pitting easily occurs due to a lack of contact fatigue strength and the like.

**[0009]** Therefore, the present inventor has tried to develop a carburized alloy steel having improved physical properties such as hardness, strength, toughness, fatigue strength, and a fatigue life, and a method of manufacturing the same.

SUMMARY

**[0010]** The present disclosure has been made in an effort to provide a carburized alloy steel including carbon (C), silicon (Si), manganese (Mn), chromium (Cr), molybdenum (Mo), niobium (Nb), vanadium (V), titanium (Ti), nitrogen (N), boron (B), and the like to improve physical properties such as hardness, strength, and toughness and thus have superior durability, and a method of manufacturing the same.

**[0011]** An exemplary embodiment of the present invention provides a carburized alloy steel including: based on a total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), and a balance of iron (Fe).

**[0012]** In certain embodiments, a content of carbon (C) may be 0.18 to 0.33 wt %, a content of silicon (Si) may be 0.69 to 1.06 wt %, a content of manganese (Mn) may be 0.74 to 0.98 wt %, a content of chromium (Cr) may be 3.2 to 5.3 wt %, a content of molybdenum (Mo) may be 0.29 to 0.38 wt %, a content of niobium (Nb) may be 0.062 to 0.064 wt %, a content of vanadium (V) may be 0.19 to 0.27 wt %, a content of titanium (Ti) may be 0.14 to 0.18 wt %, a content of nitrogen (N) may be 0.0051 to 0.0056 wt %, and a content of boron (B) may be 0.0026 to 0.0043 wt %.

**[0013]** In certain embodiments, a content of carbon (C) may be 0.18 wt %, a content of silicon (Si) may be 1.06 wt %, a content of manganese (Mn) may be 0.98 wt %, a content of chromium (Cr) may be 5.3 wt %, a content of molybdenum (Mo) may be 0.38 wt %, a content of niobium (Nb) may be 0.064 wt %, a content of vanadium (V) may be 0.27 wt %, a content of titanium (Ti) may be 0.14 wt %, a content of nitrogen (N) may be 0.0051 wt %, and a content of boron (B) may be 0.0026 wt %.

**[0014]** In certain embodiments, a transmission component of a vehicle may include a carburized alloy steel according to the present disclosure.

**[0015]** Meanwhile, another exemplary embodiment of the present invention provides a method of manufacturing a carburized alloy steel, including: a first step of manufacturing the alloy steel including, based on a total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), and a balance of iron (Fe) and the like. A second step includes carburizing heat-treating the alloy steel at about 880 to 940° C. for about 1.5 to 2 hours. In a third step, the carburized

heat-treated alloy steel is oil-quenched to about 80 to 120° C. In a fourth step, the oil-quenched alloy steel is tempered at about 170 to 200° C. for about 1 to 3 hours.

**[0016]** Herein, in certain embodiments, a content of carbon (C) may be 0.18 to 0.33 wt %, a content of silicon (Si) may be 0.69 to 1.06 wt %, a content of manganese (Mn) may be 0.74 to 0.98 wt %, a content of chromium (Cr) may be 3.2 to 5.3 wt %, a content of molybdenum (Mo) may be 0.29 to 0.38 wt %, a content of niobium (Nb) may be 0.062 to 0.064 wt %, a content of vanadium (V) may be 0.19 to 0.27 wt %, a content of titanium (Ti) may be 0.14 to 0.18 wt %, a content of nitrogen (N) may be 0.0051 to 0.0056 wt %, and a content of boron (B) may be 0.0026 to 0.0043 wt %.

**[0017]** In certain embodiments, a content of carbon (C) may be 0.18 wt %, a content of silicon (Si) may be 1.06 wt %, a content of manganese (Mn) may be 0.98 wt %, a content of chromium (Cr) may be 5.3 wt %, a content of molybdenum (Mo) may be 0.38 wt %, a content of niobium (Nb) be 0.064 wt %, a content of vanadium (V) may be 0.27 wt %, a content of titanium (Ti) may be 0.14 wt %, a content of nitrogen (N) may be 0.0051 wt %, and a content of boron (B) may be 0.0026 wt %.

**[0018]** In some embodiments of the present invention having the aforementioned constitution, it is possible to improve durability such as hardness, strength, toughness, fatigue strength, and a fatigue life of a carburized alloy steel and facilitate strengthening of the carburized alloy steel, and thus secure a degree of freedom in design of a vehicle and reduce manufacturing costs through a thickness reduction, a weight reduction of about 20%, and the like.

#### DETAILED DESCRIPTION

**[0019]** Terms or words used in the present specification and claims should not be interpreted as being limited to typical or dictionary meanings, but should be interpreted as having meanings and concepts which comply with the technical spirit of the present invention, based on the principle that an inventor can appropriately define the concept of the term to describe his/her own invention in the best manner.

**[0020]** Hereinafter, certain embodiments of the present invention will be described in detail. The present disclosure relates to a carburized alloy steel having superior durability and a method of manufacturing the same. In one aspect, the present disclosure relates to a carburized alloy steel having superior durability.

**[0021]** The carburized alloy steel having superior durability according to certain embodiments of the present invention includes, based on a total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), a balance of iron (Fe), an inevitable impurity, and the like.

**[0022]** In certain embodiments, a content of carbon (C) may be 0.18 wt %, a content of silicon (Si) may be 1.06 wt %, a content of manganese (Mn) may be 0.98 wt %, a content of chromium (Cr) may be 5.3 wt %, a content of molybdenum (Mo) may be 0.38 wt %, a content of niobium (Nb) may be 0.064 wt %, a content of vanadium (V) may be 0.27 wt %, a

content of titanium (Ti) may be 0.14 wt %, a content of nitrogen (N) may be 0.0051 wt %, and a content of boron (B) may be 0.0026 wt %.

**[0023]** In certain embodiments, the impurities may include aluminum (Al), oxygen (O), phosphorus (P), sulfur (S), and the like. In certain embodiments, a content of aluminum (Al) may be 0.006 wt %, a content of oxygen (O) may be 0.0004 wt %, a content of phosphorus (P) may be 0.011 wt %, and a content of sulfur (S) may be 0.005 wt %.

**[0024]** In more detail, the reason why a numerical value of a component constituting the heat resistant cast steel according to certain embodiments of the present invention is limited is as follows.

**[0025]** (1) 0.1 to 0.35 wt % of Carbon (C)

**[0026]** Carbon (C) is the strongest interstitial matrix strengthening element among chemical components, and is combined with an element such as chromium (Cr) to form a carbide and thus improve strength, hardness, and the like and performs a role of increasing surface hardness during carburizing.

**[0027]** For the aforementioned role, it is preferable that the content of carbon (C) be about 0.1 to 0.35 wt % based on the total weight of the alloy steel. Herein, when the content of carbon (C) is less than about 0.1 wt %, strength of the alloy steel may be reduced, and it may be difficult to secure hardness by carburizing. On the other hand, when the content of carbon (C) is more than about 0.35 wt %, core hardness of the alloy steel is increased due to excessive carburizing to reduce total toughness of the alloy steel.

**[0028]** (2) 0.1 to 2 wt % of Silicon (Si)

**[0029]** Silicon (Si) performs a role of suppressing formation of a pin hole of the alloy steel as a deoxidizer, increasing strength of the alloy steel by a solid-solution strengthening effect by being solid-dissolved in a matrix, and increasing activity of carbon (C) and the like. For the aforementioned role, it is preferable that the content of silicon (Si) be about 0.1 to 2 wt % based on the total weight of the alloy steel. Herein, when the content of silicon (Si) is less than about 0.1 wt %, an effect of the deoxidizer hardly exists, and on the other hand, in the case where the content of silicon (Si) is more than about 2 wt %, the solid-solution strengthening effect of the matrix is excessively increased to reduce formability, a carburizing property, and the like.

**[0030]** (3) 0.1 to 1.5 wt % of Manganese (Mn)

**[0031]** Manganese (Mn) performs a role of improving a quenching property of the alloy steel and improving strength of the alloy steel and the like. For the aforementioned role, it is preferable that the content of manganese (Mn) be about 0.1 to 1.5 wt %. Herein, in the case where the content of manganese (Mn) is less than about 0.1 wt %, a sufficient quenching property and the like may not be secured, and on the other hand, in the case where the content of manganese (Mn) is more than about 1.5 wt %, grain boundary oxidation may occur, and mechanical properties of the alloy steel may be reduced.

**[0032]** (4) 3 to 5.5 wt % of Chromium (Cr)

**[0033]** Chromium (Cr) performs a role of improving a quenching property of the alloy steel, simultaneously providing hardenability and micronizing a tissue of the alloy steel, and promoting carburizing and reducing a carburizing time by being reacted with carbon (C) to form a fine carbide. For the aforementioned role, it is preferable that the content of chromium (Cr) be about 3 to 5.5 wt %. Herein, when the content of chromium (Cr) is less than about 3 wt %, an effect

of carbide formation is reduced, and on the other hand, when the content of chromium (Cr) is more than about 5.5 wt %, toughness of the alloy steel is reduced, grain boundary oxidation occurs, and an effect according to an increase in content is insignificant to cause an increase in manufacturing cost.

**[0034]** (5) 0.2 to 0.5 wt % of Molybdenum (Mo)

**[0035]** Molybdenum (Mo) performs a role of improving hardenability, toughness, and the like of the alloy steel after quenching or tempering and providing brittleness resistance. For the aforementioned role, it is preferable that the content of molybdenum (Mo) be about 0.2 to 0.5 wt %. Herein, when the content of molybdenum (Mo) is less than about 0.2 wt %, hardenability and toughness of the alloy steel and the like may not be sufficiently secured, and on the other hand, when the content of molybdenum (Mo) is more than about 0.5 wt %, processability and productivity of the alloy steel and the like may be reduced.

**[0036]** (6) More than 0 wt % and 0.07 wt % or Less of Niobium (Nb)

**[0037]** Niobium (Nb) is combined with nitrogen to form a nitride and the like to perform a role of micronizing crystal grains, increasing a recrystallization temperature, and facilitating high temperature carburizing, and thus improving hardenability and toughness of the alloy steel and the like. For the aforementioned role, it is preferable that the content of niobium (Nb) be more than 0 wt % and about 0.07 wt % or less. Herein, when the content of niobium (Nb) is more than about 0.07 wt %, an effect of niobium (Nb) may be saturated, toughness may be reduced, and processability, productivity, and the like may be reduced.

**[0038]** (7) More than 0 wt % and 0.3 wt % or Less of Vanadium (V)

**[0039]** Vanadium (V) performs a role of forming precipitates such as carbides, strengthening a matrix tissue through a precipitation strengthening effect, improving strength and wear resistance, and micronizing crystal grains. For the aforementioned role, it is preferable that the content of vanadium (V) be more than 0 wt % and about 0.3 wt % or less. Herein, when the content of vanadium (V) is more than about 0.3 wt %, toughness and hardness of the alloy steel and the like may be reduced all the more.

**[0040]** (8) More than 0 wt and 0.2 wt % or Less of Titanium (Ti)

**[0041]** Titanium (Ti) performs a role of forming a carbonitride to suppress growth of the crystal grains and improve high temperature stability, strength, toughness, and the like. For the aforementioned role, it is preferable that the content of titanium (Ti) be more than 0 wt % and about 0.2 wt % or less. Herein, when the content of titanium (Ti) is more than about 0.2 wt %, a coarse precipitate may be formed, and due to a reduction in low temperature impact property and saturation of the effect thereof, a manufacturing cost may be increased.

**[0042]** (9) More than 0 wt % and 0.015 wt % or Less of Nitrogen (N)

**[0043]** Nitrogen (N) performs a role of micronizing austenite crystal grains and improving tensile strength, yield strength, and elongation of the alloy steel and the like. For the aforementioned role, it is preferable that the content of nitrogen (N) be more than 0 wt % and about 0.015 wt % or less. Herein, when the content of nitrogen (N) is about 0.015 wt % or less, brittleness may be caused and a durability life and the like may be reduced.

**[0044]** (10) 0.002 to 0.005 wt % of Boron (B)

**[0045]** Boron (B) performs a role of improving hardenability of the alloy steel and the like, and to this end, it is preferable that the content of boron (B) be about 0.002 to 0.005 wt %. Herein, when the content of boron (B) is less than about 0.002 wt %, it may be difficult to secure sufficient hardenability of the alloy steel, and on the other hand, when the content of boron (B) is more than about 0.005 wt %, toughness and ductility of the alloy steel and the like may be reduced to reduce impact resistance and the like.

**[0046]** Since the carburized alloy steel having the aforementioned constitution according to certain embodiments of the present invention has superior hardness, strength, toughness, fatigue strength, and fatigue life, it is advantageous that the carburized alloy steel be applied to vehicle parts and the like. It is particularly advantageous that the carburized alloy steel be applied to automatic or manual transmissions and the like, and among the transmissions, it is particularly advantageous that the carburized alloy steel be applied to carriers, annulus gears, gears, shafts, synchronizer hubs, or the like.

**[0047]** Hereinafter, in another aspect, other embodiments of the present invention relate to a method of manufacturing a carburized alloy steel having superior durability.

**[0048]** The carburized alloy steel having superior durability according to the present invention may be appropriately manufactured by a person with skill in the art with reference to a publicly known technology. To be more specific, the method of manufacturing the carburized alloy steel having superior durability according to certain embodiments of the present invention includes a first step of manufacturing the alloy steel for carburizing including, based on the total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), a balance of iron (Fe), an inevitable impurity, and the like. In a second step the alloy steel undergoes a carburizing heat-treating at about 880 to 940° C. for about 1.5 to 2 hours. A third step includes oil-quenching the carburized heat-treated alloy steel to about 80 to 120° C. In a fourth step, the oil-quenched alloy steel is tempered at about 170 to 200° C. for about 1 to 3 hours.

**[0049]** In certain embodiments, in the second step, in the case where a heat-treating temperature is less than about 880° C., since a heat-treating time is increased, productivity may be reduced, and in the case where a heat-treating time is less than about 1.5 hours, times of supplying, injecting, and diffusing carbon (C) are short, and thus carburizing may not be sufficiently performed.

**[0050]** On the other hand, in the second step, in the case where the heat-treating temperature is more than about 940° C., recrystallization of the alloy steel may occur to reduce mechanical properties, and in the case where the heat-treating time is more than about 2 hours, occurrence of over-carburizing and thermal deformation are concerned, and a manufacturing cost is increased.

**[0051]** In the third step, in the case where an oil quenching temperature is less than about 80° C., or in the fourth step, in the case where the tempering temperature is less than about 170° C., it may be difficult to secure toughness of the alloy steel due to non-formation of residual austenite. In the case where the oil quenching temperature is more than about 120° C. or in the case where the tempering temperature is more than about 200° C., a fatigue property of the alloy steel and the like may be reduced due to an increase of the residual austenite during a rapid cooling process, and in the case where the tempering time is more than about 3 hours, it may be difficult to improve the durability life and the like due to a rapid reduction in hardness of the alloy steel.

**[0052]** Meanwhile, in the first step, in certain embodiments, a content of carbon (C) may be 0.18 wt %, a content of silicon (Si) may be 1.06 wt %, a content of manganese (Mn) may be 0.98 wt %, a content of chromium (Cr) may be 5.3 wt %, a content of molybdenum (Mo) may be 0.38 wt %, a content of niobium (Nb) may be 0.064 wt %, a content of vanadium (V) may be 0.27 wt %, a content of titanium (Ti) may be 0.14 wt %, a content of nitrogen (N) may be 0.0051 wt %, and a content of boron (B) may be 0.0026 wt %. In certain embodiments, an impurity may include aluminum (Al), oxygen (O), phosphorus (P), sulfur (S), and the like. In certain embodiments, the content of aluminum (Al) may be 0.006 wt %, the content of oxygen (O) may be 0.0004 wt %, the content of phosphorus (P) may be 0.011 wt %, and the content of sulfur (S) may be 0.005 wt %.

#### Example

**[0053]** Hereinafter, certain embodiments of the present invention will be described in more detail through the Examples. These Examples are only for illustrating certain embodiments of the present invention, and it will be obvious

TABLE 1

Classification	Unit	Comparative	Comparative	Comparative	Exam- ple 1	Exam- ple 2
		Exam- ple 1	Exam- ple 2	Exam- ple 3		
C	wt %	0.21	0.20	0.19	0.33	0.18
Si	wt %	0.62	0.61	0.62	0.69	1.06
Mn	wt %	0.64	0.60	0.57	0.74	0.98
Cr	wt %	2.05	3.63	3.74	3.2	5.3
Mo	wt %	0.39	—	0.18	0.29	0.38
Nb	wt %	0.028	0.028	0.027	0.062	0.064
V	wt %	—	—	—	0.19	0.27
Ti	wt %	—	0.002	—	0.18	0.14
B	wt %	—	0.012	—	0.0043	0.0026
N	wt %	0.0078	0.0065	0.0082	0.0056	0.0051
Al	wt %	0.03	0.008	0.012	0.007	0.006
O	wt %	0.0005	0.001	0.001	0.0005	0.0004
P	wt %	0.012	0.01	0.01	0.012	0.011
S	wt %	0.005	0.007	0.007	0.005	0.005

**[0055]** Table 1 is a table where the constitutional components and the contents of Comparative Examples 1 to 3 according to the existing alloy steel and the constitutional components and the contents of Examples 1 and 2 according to the present invention are compared, and aluminum (Al), oxygen (O), phosphorus (P), and sulfur (S) are impurities in a very small amount that are included in the Comparative Examples and the Examples.

TABLE 2

Classification	Comparative	Comparative	Comparative	Example 1	Example 2
	Example 1	Example 2	Example 3		
Carburizing temperature (° C.)/hour (h)	930/2	940/1.67	930/1.83	880/1.5	940/1.83
Quenching oil temperature (° C.)	110	100	110	80	120
Tempering temperature (° C.)/hour (h)	180/2	170/2	190/2.5	170/1.5	190/3

to those skilled in the art that the scope of the present invention is not interpreted to be limited by these Examples.

**[0054]** In order to compare physical properties of the carburized alloy steel having superior durability according to the present disclosure, Comparative Examples and Examples having the components as described in the following Table 1, to which the conditions of the carburizing temperature and time, the quenching oil temperature, and the tempering temperature and time described in the following Table 2 were applied, were manufactured.

**[0056]** Table 2 is a table where among the manufacturing conditions of Comparative Examples 1 to 3 and Examples 1 and 2 having the constitutional components and the contents of Table 1, the carburizing temperatures and times, the quenching oil temperatures, and the tempering temperatures and times are compared. Herein, all of Comparative Examples 1 to 3 and Examples 1 and 2 satisfied the carburizing temperature and time, the quenching oil temperature, and the tempering temperature and time according to embodiments of the present invention.

TABLE 3

Classification	Comparative	Comparative	Comparative	Example 1	Example 2
	Example 1	Example 2	Example 3		
Surface hardness (HV)	740	730	740	810	815

TABLE 3-continued

Classification	Comparative Example 1	Comparative Example 2	Comparative Example 3	Example 1	Example 2
Core hardness (HV)	495	507	514	560	575
Tensile strength (kgf/cm <sup>2</sup> )	1063	1207	1218	1202	1232
Yield strength (kgf/cm <sup>2</sup> )	957	1073	1091	1082	1108
Carburizing depth (mm)	0.71	0.71	0.73	0.76	0.78
Impact value (J)	27.8	24.6	39.8	46.4	47.2
Rotation bending strength (K)	105	11.5	125	142	144
Contact fatigue life (times, cycle)	4,150,000	8,370,000	9,020,000	11,200,000	12,400,000

**[0057]** Table 3 is a table where after Comparative Examples 1 to 3 and Examples 1 and 2 having the constitutional components and the contents of Table 1 are manufactured according to the condition of Table 2, surface hardnesses, core hardnesses, tensile strengths, yield strengths, carburizing depths, impact values, rotation bending strengths, and contact fatigues are compared.

**[0058]** Surface hardness and core hardness were measured according to the KS B 0811 measurement method by using the Micro Vickers Hardness tester. In the case of rotation bending strength, the L10 life was measured according to the KS B ISO 1143 measurement method under the condition of a maximum flexion moment of about 20 kgfm, a rotation number of about 200 to 3000 RPM, a maximum load of about 100 kg or less, and electric power of three phases, 220 V, and 7 kW by using the standard line diameter of about 4 mm through the rotation bending fatigue tester. The L10 life is the rating fatigue life of the specimen, and means the total rotation number of the rotation bending fatigue tester until about 10% of the specimen is damaged. Further, in the case of contact fatigue, the rotation number of the roller for contact fatigue test before cracks were formed in the specimen was measured under conditions of surface pressure of about 332 kg/mm<sup>2</sup>, lubricant temperature of about 80° C., and lubricant amount of about 1.2 l/min by using the contact fatigue experiment apparatus.

**[0059]** Examples 1 and 2 exhibited values of surface hardness and core hardness that were both unexpectedly higher than those of Comparative Examples 1 to 3, the values of tensile strength and yield strength were highest in Example 2, the carburizing depth of Examples 1 and 2 was larger than that of Comparative Examples 1 to 3, and the impact value, rotation bending strength, and the contact fatigue life of Examples 1 and 2 were unexpectedly superior to those of Comparative Examples 1 to 3.

**[0060]** Therefore, it could be confirmed that in Examples 1 and 2 according to embodiments of the present invention, as compared to Comparative Examples 1 to 3, surface hardness was unexpectedly superior by about 10%, core hardness was unexpectedly superior by about 12%, tensile strength and yield strength were each unexpectedly superior by about 5%, the carburizing depth was unexpectedly superior by about 7%, the impact value was superior by about 52%, rotation bending strength was unexpectedly superior by about 24%, and the contact fatigue life was unexpectedly superior by about 72%.

**[0061]** Particularly, it can be confirmed that since Example 2 according to an embodiment of the present invention has physical properties that are unexpectedly superior to those of Example 1 as well as Comparative Examples 1 to 3, the constitutional component and the content of Example 2 are more preferable than Example 1 under certain conditions.

**[0062]** As described above, the present invention has been described in relation to specific embodiments of the present invention, but the embodiments are only illustrations and the present invention is not limited thereto. Embodiments described may be changed or modified by those skilled in the art to which the present invention pertains without departing from the scope of the present invention, and various alterations and modifications are possible within the technical spirit of the present invention and the equivalent scope of the claims which will be described below.

What is claimed is:

1. A carburized alloy steel comprising:

based on a total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), and a balance of iron (Fe).

2. The carburized alloy steel of claim 1, wherein a content of carbon (C) is 0.18 to 0.33 wt %, a content of silicon (Si) is 0.69 to 1.06 wt %, a content of manganese (Mn) is 0.74 to 0.98 wt %, a content of chromium (Cr) is 3.2 to 5.3 wt %, a content of molybdenum (Mo) is 0.29 to 0.38 wt %, a content of niobium (Nb) is 0.062 to 0.064 wt %, a content of vanadium (V) is 0.19 to 0.27 wt %, a content of titanium (Ti) is 0.14 to 0.18 wt %, a content of nitrogen (N) is 0.0051 to 0.0056 wt %, and a content of boron (B) is 0.0026 to 0.0043 wt %.

3. The carburized alloy steel of claim 1, wherein a content of carbon (C) is 0.18 wt %, a content of silicon (Si) is 1.06 wt %, a content of manganese (Mn) is 0.98 wt %, a content of chromium (Cr) is 5.3 wt %, a content of molybdenum (Mo) is 0.38 wt %, a content of niobium (Nb) is 0.064 wt %, a content of vanadium (V) is 0.27 wt %, a content of titanium (Ti) is 0.14 wt %, a content of nitrogen (N) is 0.0051 wt %, and a content of boron (B) is 0.0026 wt %.

4. A transmission component of a vehicle comprising the alloy steel of claim 1.

5. A transmission component of a vehicle comprising the alloy steel of claim 2.

6. A transmission component of a vehicle comprising the alloy steel of claim 3.

7. A method of manufacturing a carburized alloy steel, comprising:

a first step of manufacturing the alloy steel, the alloy steel comprising, based on a total weight of the alloy steel, 0.1 to 0.35 wt % of carbon (C), 0.1 to 2 wt % of silicon (Si), 0.1 to 1.5 wt % of manganese (Mn), 3 to 5.5 wt % of chromium (Cr), 0.2 to 0.5 wt % of molybdenum (Mo), more than 0 wt % and 0.07 wt % or less of niobium (Nb), more than 0 wt % and 0.3 wt % or less of vanadium (V), more than 0 wt % and 0.2 wt % or less of titanium (Ti), more than 0 wt % and 0.015 wt % or less of nitrogen (N), 0.002 to 0.005 wt % of boron (B), and a balance of iron (Fe);

a second step of carburizing heat-treating the alloy steel at 880 to 940° C. for 1.5 to 2 hours;

a third step of oil-quenching the carburized alloy steel to 80 to 120° C.; and

a fourth step of tempering the oil-quenched alloy steel at 170 to 200° C. for 1 to 3 hours.

8. The method of claim 7, wherein a content of carbon (C) is 0.18 to 0.33 wt %, a content of silicon (Si) is 0.69 to 1.06 wt %, a content of manganese (Mn) is 0.74 to 0.98 wt %, a content of chromium (Cr) is 3.2 to 5.3 wt %, a content of molybdenum (Mo) is 0.29 to 0.38 wt %, a content of niobium (Nb) is 0.062 to 0.064 wt %, a content of vanadium (V) is 0.19 to 0.27 wt %, a content of titanium (Ti) is 0.14 to 0.18 wt %, a content of nitrogen (N) is 0.0051 to 0.0056 wt %, and a content of boron (B) is 0.0026 to 0.0043 wt %.

9. The method of claim 7, wherein a content of carbon (C) is 0.18 wt %, a content of silicon (Si) is 1.06 wt %, a content of manganese (Mn) is 0.98 wt %, a content of chromium (Cr) is 5.3 wt %, a content of molybdenum (Mo) is 0.38 wt %, a content of niobium (Nb) is 0.064 wt %, a content of vanadium (V) is 0.27 wt %, a content of titanium (Ti) is 0.14 wt %, a content of nitrogen (N) is 0.0051 wt %, and a content of boron (B) is 0.0026 wt %.

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