(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 085 795 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
26.10.2016 Bulletin 2016/43

(21) Application number: **15189729.5**

(22) Date of filing: **14.10.2015**

(51) Int Cl.:
C21D 1/18 (2006.01)
C22C 38/02 (2006.01)
C22C 38/04 (2006.01)
C22C 38/10 (2006.01)
C22C 38/14 (2006.01)
C22C 38/22 (2006.01)
C22C 38/54 (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

(30) Priority: **20.04.2015 KR 20150055104**

(71) Applicant: **Hyundai Motor Company**
Seoul 137-938 (KR)

(72) Inventors:
- **Cha, Sung-Chul**
  04428 Seoul (KR)
- **Hong, Seung-Hyun**
  04421 Seoul (KR)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) CARBURIZING ALLOY STEEL HAVING IMPROVED DURABILITY AND METHOD OF MANUFACTURING THE SAME

(57) A carburizing alloy steel includes 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), 0.5 to 1.5 wt% of chromium (Cr), 0.2 to 0.5 wt% of molybdenum (Mo), 0.1 to 0.6 wt% of nickel (Ni), more than 0 wt% and less than or equal to 0.07 wt% of niobium (Nb), more than 0 wt% and less than or equal to 0.5 wt% of vanadium (V), more than 0 wt% and less than or equal to 0.5 wt% of titanium (Ti), more than 0 wt% and less than or equal to 0.015 wt% of nitrogen (N), 0.00002 to 0.00005 wt% of boron (B), based on the total weight of the alloy steel, iron (Fe) as a main component.

EP 3 085 795 A1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. §119 to Korean Patent Application No. 10-2015-55104, filed on April 20, 2015, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to a carburizing alloy steel having improved durability and a method of manufacturing the same, and more particularly, to a carburizing alloy steel having an appropriate configuration component and content to effectively carburize a surface of the alloy steel, thus improving hardness, strength, toughness, fatigue strength, a fatigue life, and the like, and a method of manufacturing the same.

BACKGROUND

[0003] Recently, an environmental problem has been on the rise around the globe, and thus, a method of reducing fuel to cope with this problem encompassing all industries has been sought. In order to reduce the fuel, examples of a solution proposed include improving efficiency of a vehicle engine and reducing a vehicle weight. By reducing the vehicle weight, fuel efficiency of the vehicle increases. However, when reducing the vehicle weight, there occurs a problem in that strength and durability required in a vehicle are not satisfied. Therefore, it is the greatest goal of a vehicle industry to solve this problem.

[0004] Therefore, in the automobile industry, various environmentally-friendly vehicles have been developed to reduce a discharge amount of carbon dioxide to 95 g/km which is 27% lower than that a current discharge amount thereof by 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.

[0005] Generally, in order to cope with an increase in number of parts or an increase in weight, the weight of a material is reduced. In this case, as a weight reduction method, a heat treatment technology for implementing a high strength of the material or curing a material surface is frequently used. Further, in order to cope with complicated shapes of parts, precise joining, low distortion welding, and low distortion heat treatment technologies are used. In addition to this, a technology of reducing distortion caused by heat treatment, and noise reduction and dust removing technologies are used.

[0006] Particularly, a high performance and high efficiency technology of engines and transmissions for maximizing fuel economy of vehicles has been developed. This technology includes an increase in number of gears, a novel concept driveaway device, high efficiency of a two-pump system, a fusion hybrid technology, technologies relating to an automatic/manual fusion transmission and a hybrid transmission, and the like.

[0007] An alloy steel used in a technology relating to the engines and the transmissions is used in parts of the engines, carriers of a transmission, gears, shafts, synchronizer hubs, or the like, and a use ratio of the alloy steel corresponds to 32 to 40% based on the weight of the engine and about 58 to 62 wt% based on the weight of the transmission. Particularly, in the gears of the transmission and the like, development of high strengthening and high durability materials in respect to achieving the requirements of a weight reduction and downsizing has been continuously required. However, a technology relating to downsizing or improving fuel efficiency has problems in that a load applied to the parts of the engines is increased, and a quality of the parts is reduced and a durability life is reduced due to burning, friction, abrasion, and the like.

[0008] Generally, the gears of the transmission directly transfer engine power to a differential system and effectively transfer rotation or power between two or more shafts so that engine power is attuned to a driving state of the vehicle, and receive bending stress and contact stress simultaneously. When durability of the material is insufficient for the gears, fatigue failure (tooth breakage) due to lack of bending fatigue strength and fatigue damage (pitting) due to lack of contact fatigue strength frequently occur. Therefore, in the gears, physical properties such as high hardness, strength, toughness, fatigue strength, and a fatigue life are required.

[0009] As an alternative of the aforementioned requirement, currently, a carburizing 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_2), and the like is used. However, tooth breakage and pitting easily occur when using the carburizing steel.

[0010] Therefore, a technology of improving physical properties such as hardness, strength, toughness, fatigue strength, and a fatigue life of a carburizing alloy steel, and a method of manufacturing the same has been developed.

SUMMARY

[0011] The present disclosure has been made in an effort to provide a carburizing alloy steel including carbon (C), silicon (Si), manganese (Mn), chromium (Cr), molybdenum (Mo), niobium (Nb), vanadium (V), nickel (Ni), titanium (Ti), nitrogen (N), boron (B), tungsten (W), zirconium (Zr), cobalt (Co), and yttrium (Y) to improve physical properties such as hardness, strength, and toughness and thus improve durability, and a method of manufacturing the same.

[0012] An exemplary embodiment of the present invention provides a carburizing alloy steel including: based on a total weight of the alloy steel, iron (Fe) as a main component, 0.1 to 0.35 wt% of carbon (C), 0.1 to 2.0 wt% of silicon (Si), 0.1 to 1.5 wt% of manganese (Mn), 0.5 to 1.5 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), 0.1 to 0.6 wt% of nickel (Ni), more than 0 wt% and 0.5 wt% or less of vanadium (V), more than 0 wt% and 0.5 wt% or less of titanium (Ti), more than 0 wt% and 0.015 wt% or less of nitrogen (N), and 0.00002 to 0.00005 wt% of boron (B).

[0013] The carburizing alloy steel of the present invention further includes tungsten (W), and in this case, a content of tungsten (W) may be more than 0 wt% and 0.4 wt% or less.

[0014] The carburizing alloy steel of the present invention further includes zirconium (Zr), and in this case, a content of zirconium (Zr) may be more than 0 wt% and 0.01 wt% or less.

[0015] The carburizing alloy steel of the present invention further includes cobalt (Co), and in this case, a content of cobalt (Co) may be more than 0 wt% and 5 wt% or less.

[0016] The carburizing alloy steel of the present invention further includes yttrium (Y), and in this case, a content of yttrium (Y) may be more than 0 wt% and 2 wt% or less.

[0017] The carburizing alloy steel of the present invention further includes one or more of tungsten (W), zirconium (Zr), cobalt (Co), or yttrium (Y), and a content of tungsten (W) may be more than 0 wt% and 0.4 wt% or less, a content of zirconium (Zr) may be more than 0 wt% and 0.01 wt% or less, a content of cobalt (Co) may be more than 0 wt% and 5 wt% or less, and a content of yttrium (Y) may be more than 0 wt% and 2 wt% or less.

[0018] Another exemplary embodiment of the present invention provides a method of manufacturing a carburizing alloy steel, the method including: mixing materials of the alloy steel for carburizing; carburizing the alloy steel at 930 to 980°C for 1.6 to 4 hours; oil-quenching the carburized alloy steel at 80 to 120°C; and tempering the oil-quenched alloy steel at 150 to 200°C for 1 to 3 hours.

[0019] Yet another exemplary embodiment of the present invention provides a transmission for a vehicle manufactured by using the carburizing alloy steel.

[0020] According to a carburizing alloy steel that is the present invention, which includes, based on the total weight of the alloy steel, iron (Fe) as a main component, carbon (C), silicon (Si), manganese (Mn), chromium (Cr), molybdenum (Mo), niobium (Nb), vanadium (V), nickel (Ni), titanium (Ti), nitrogen (N), boron (B), tungsten (W), zirconium (Zr), cobalt (Co), and yttrium (Y), and a method of manufacturing the carburizing alloy steel, durability such as hardness, strength, toughness, fatigue strength, and a fatigue life of a material is improved. Moreover, it is possible to achieve high strengthening of the carburizing alloy steel, and thus a thickness reduction, a weight reduction of about 20%, and the like, to secure the degree of freedom in design of a vehicle and reduce manufacturing costs.

[0021] According to a transmission for a vehicle manufactured by using the carburizing alloy steel that is the present invention, it is possible to improve durability of the vehicle and reduce weight of the vehicle and thus increase fuel efficiency and prevent environmental pollution.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0022] Hereinafter, exemplary embodiments of the present inventive concept will be described in detail. Prior to this, 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 disclosure, 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. Accordingly, the embodiment described in the present specification is just exemplary embodiment of the present inventive concept but does not represent all technical spirits of the present invention. Therefore, it should be understood that there are various equivalents and modifications replacing the embodiments at the time of filing of the present application.

[0023] Hereinafter, the present disclosure will be described in detail. The present invention relates to a carburizing alloy steel having improved durability and a method of manufacturing the same, and in one aspect, the present disclosure relates to a carburizing alloy steel having improved durability.

[0024] The carburizing alloy steel having improved durability according to the present disclosure may include, based on the total weight of the alloy steel, iron (Fe) as a main component, 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), 0.5 to 1.5 wt% of chromium (Cr), 0.2 to 0.5 wt% of molybdenum (Mo), 0.1 to 0.6 wt% of nickel (Ni), more than 0 wt% and 0.07 wt% or less of niobium (Nb), more than 0 wt% and 0.5 wt% or less of vanadium (V), more than 0 wt% and 0.5 wt% or less of titanium (Ti), more than 0 wt% and 0.015 wt% or less of nitrogen (N), and 0.00002 to 0.00005 wt% of boron (B).

[0025] The present disclosure may be formed by selectively adding one or more of more than 0 wt% and 0.4 wt% or less of tungsten (W), more than 0 wt% and 0.01 wt% or less of zirconium (Zr), more than 0 wt% and 5 wt% or less of cobalt (Co), or more than 0 wt% and 2 wt% or less of yttrium (Y).

[0026] In more detail, the reason why a numerical value of a component configuring the carburizing alloy steel according to the present invention is limited is as follows.

(1) 0.1 to 0.35 wt% of carbon (C)

[0027] 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, increasing surface hardness, and generating a precipitate carbide during carburizing.

[0028] For the aforementioned role, the content of carbon (C) may be about 0.1 to 0.35 wt% based on the total weight of the alloy steel. Herein, in the case where 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, in the case where the content of carbon (C) is more than about 0.35 wt%, core hardness of the alloy steel increases due to excessive carburizing to reduce total toughness of the alloy steel.

(2) 0.1 to 2 wt% of silicon (Si)

[0029] Silicon (Si) hinders carburizing when added in an excessive amount, but suppresses 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-solved in a matrix, and increasing activity of carbon (C) and the like.

[0030] For the aforementioned role, the content of silicon (Si) may be about 0.1 to 2.0 wt% based on the total weight of the alloy steel. Herein, in the case where 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 2.0 wt%, there is a problem in that the solid-solution strengthening effect of the matrix is excessively increased to reduce formability, a carburizing property, and the like.

(3) 0.1 to 1.5 wt% of manganese (Mn)

[0031] Manganese (Mn) improves a quenching property of the alloy steel and improves strength of the alloy steel and the like. For the aforementioned role, the content of manganese (Mn) may be about 0.1 to 1.5 wt%.

[0032] Herein, when the content of manganese (Mn) is less than about 0.1 wt%, a sufficient quenching property and the like may not be secured. On the other hand, when the content of manganese (Mn) is more than about 1.5 wt%, grain boundary oxidation occurs, and mechanical properties of the alloy steel are reduced.

(4) 1.5 to 3.0 wt% of chromium (Cr)

[0033] Chromium (Cr) improves a quenching property of the alloy steel, provides hardenability and micronizing a tissue of the alloy steel, and promotes carburizing and reduces a carburizing time by being reacted with carbon (C) to form a fine carbide. Further, formation of the precipitate carbide and cementite increases.

[0034] For the aforementioned role, the content of chromium (Cr) be about 1.5 to 3.0 wt%. When the content of chromium (Cr) is less than about 1.5 wt%, a carbide formation effect decreases. When the content of chromium (Cr) is more than about 3.0 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.

(5) 0.2 to 0.5 wt% of molybdenum (Mo)

[0035] Molybdenum (Mo) increases formation of the carbide, increases stability at high temperatures, and reduces activity of carbon. Further, molybdenum (Mo) improves hardenability, toughness, and the like of the alloy steel and provides brittleness resistance of the alloy steel after quenching or tempering.

[0036] The content of molybdenum (Mo) may 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 (machinability) and productivity of the alloy steel and the like decrease.

(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 micronize crystal grains, increase a recrystallization temperature, and facilitate high temperature carburizing, and thus improving hardenability and toughness of the alloy steel and the like. Here, the content of niobium (Nb) may be more than 0 wt% and about 0.07 wt% or less.
[0038] When the content of niobium (Nb) is more than about 0.07 wt%, niobium (Nb) is saturated and toughness, processability, productivity, and the like decrease. On the other hand, when niobium (Nb) is not included, it is difficult to perform a carburizing process at a high temperature.

(7) More than 0 wt% and 0.3 wt% or less of vanadium (V)

[0039] Vanadium (V) forms precipitates such as carbides, strengthens a matrix tissue through a precipitation strengthening effect, improves strength and wear resistance, and micronizes crystal grains. Further, vanadium (V) reduces carbon activity.
[0040] For the aforementioned role, the content of vanadium (V) may be more than 0 wt% and about 0.3 wt% or less. Herein, in the case where the content of vanadium (V) is more than about 0.3 wt%, toughness and hardness of the alloy steel and the like may decrease all the more.

(8) More than 0 wt% and 0.2 wt% or less of titanium (Ti)

[0041] Titanium (Ti) forms carbonitride to suppress growth of the crystal grains and improves high temperature stability, strength, toughness, and the like.
[0042] Here, the content of titanium (Ti) may be more than 0 wt% and about 0.2 wt% or less. When the content of titanium (Ti) is more than about 0.2 wt%, a coarse precipitate is formed, and due to a reduction in a low temperature impact property and saturation of the effect thereof, manufacturing costs increase.

(9) More than 0 wt% and 0.015 wt% or less of nitrogen (N)

[0043] Nitrogen (N) stabilizes austenite, micronizing crystal grains thereof, and improves tensile strength, yield strength, and elongation of the alloy steel and the like. However, a durability life may decrease due to formation of impurities. Here, the content of nitrogen (N) may be more than 0 wt% and about 0.015 wt% or less.
[0044] 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.

(10) 0.00002 to 0.00005 wt% of boron (B)

[0045] Boron (B) improves hardenability, tensile strength, impact resistance, and strength of the alloy steel, and the like, and prevents corrosion. However, weldability decreases.
[0046] For this, in the present disclosure, the content of boron (B) may be about 0.00002 to 0.00005 wt%. When the content of boron (B) is less than about 0.00002 wt%, it is difficult to secure sufficient hardenability of the alloy steel. On the other hand, when the content of boron (B) is more than about 0.00005 wt%, toughness, ductility impact resistance, and the like decrease.

(11) 0.1 to 0.6 wt% of nickel (Ni)

[0047] Nickel (Ni) improves heat resistance and toughness. Here, the content of nickel (Ni) may be about 0.1 to 0.6 wt%.
[0048] When the content of nickel (Ni) is less than about 0.1 wt%, sufficient heat resistance and toughness may not be secured. On the other hand, when the content of nickel (Ni) is more than about 0.6 wt%, processability (machinability) and productivity of the alloy steel and the like decrease.

(12) More than 0 wt% and 0.4 wt% or less of tungsten (W)

[0049] Tungsten forms precipitate carbide to improve wear resistance and toughness at high temperatures. However, tungsten suppresses growth of a tissue to reduce scale resistance.
[0050] Therefore, in the present disclosure, the content of tungsten may be more than 0 wt% and 0.4 wt% or less. When the content of tungsten is more than 0.4 wt%, the precipitate carbide is excessively formed and toughness is reduced.

(13) More than 0 wt% and 0.01 wt% or less of zirconium (Zr)

[0051] Zirconium forms a precipitate and removes nitrogen (N), oxygen (O), and sulfur (S) to extend its life, and reduces a size of a non-metallic inclusion.
[0052] Therefore, in the present disclosure, the content of zirconium may be more than 0 wt% and 0.01 wt% or less. Herein, if the content of zirconium is more than 0.01 wt%, ZnO_2 is formed and an effect of zirconium is saturated to increase manufacturing costs.

(14) More than 0 wt% and 5 wt% or less of cobalt (Co)

[0053] Cobalt suppresses growth of grains at a high temperature to increase a quenching property. Further, the temperature increases and strength is maintained, and thus, wear resistance is increased. Additionally, cobalt improves processability. However, cobalt does not form a carbide and is irrelevant to corrosion resistance.
[0054] Therefore, in the present disclosure, the content of cobalt may be more than 0 wt% and 5 wt% or less. When the content is more than 5 wt%, cobalt may not properly form the carbide and an effect thereof is saturated thus increasing manufacturing costs.

(15) More than 0 wt% and 2 wt% or less of yttrium (Y)

[0055] Yttrium increases stability at a high temperature, improves heat resistance and toughness at high temperatures, and forms a permeation blocking oxide surface preventing oxidation and corrosion when being exposed to the high temperature. Further, seizure resistance and chemical resistance become excellent at the high temperature.
[0056] Therefore, the content of yttrium may be more than 0 wt% and 2 wt% or less. When the content of yttrium is more than 2 wt%, yttrium disturbs a role of another element, weldability is reduced, and manufacturing costs increase.
[0057] Since the carburizing alloy steel according to the present disclosure has superior hardness, strength, toughness, fatigue strength, and a fatigue life, the carburizing alloy steel may be applied to vehicle parts and the like, or applied to automatic or manual transmissions and the like. More specifically, the carburizing alloy steel may be applied to carriers, annulus gears, gears, shafts, synchronizer hubs, or the like.
[0058] Hereinafter, a method of manufacturing a carburizing alloy steel having improved durability another embodiment of the present inventive concept is described.
[0059] The carburizing alloy steel having improved durability according to the present disclosure may be manufactured by a person with ordinary skill in the art with reference to a publicly known technology. To be more specific, the method of manufacturing the carburizing alloy steel having improved durability according to the present disclosure includes mixing materials of the alloy steel for carburizing; carburizing the alloy steel at about 930 to 980°C for about 1.6 to 4 hours; oil-quenching the carburized alloy steel at about 80 to 120°C; and tempering the oil-quenched alloy steel at about 150 to 200°C for about 1 to 3 hours, and the like.
[0060] The step of mixing may include mixing the materials of the alloy steel for carburizing by adding one or more elements selected from tungsten (W), zirconium (Zr), cobalt (Co), and yttrium (Y) to carbon (C), silicon (Si), manganese (Mn), chromium (Cr), molybdenum (Mo), niobium (Nb), vanadium (V), nickel (Ni), titanium (Ti), nitrogen (N), or boron (B).
[0061] Herein, when a heat-treating temperature is less than about 930°C in the step of carburizing, since a heat-treating time increases, productivity decreases. When the heat-treating time is less than about 1.6 hours, since supplying, injecting, and diffusing carbon (C) have relatively short processing times, carburizing may not be sufficiently performed.
[0062] On the other hand, when the heat-treating temperature is more than about 980°C, recrystallization of the alloy steel may occur to reduce mechanical properties, and when the heat-treating time is more than about 4 hours, occurrence of over-carburizing and thermal deformation are concerned and manufacturing costs increase.
[0063] In the step of oil-quenching, an oil-quenching temperature is less than about 80°C. In the step of tempering, a tempering temperature is less than about 150°C. Since a residual austenite is not formed, it may be difficult to secure toughness of the alloy steel. When a tempering time is less than about 1 hour, relaxation of brittleness is insufficient, a material deviation is severe, and it is difficult to secure toughness.
[0064] On the other hand, when the oil-quenching temperature is more than about 120°C or the tempering temperature is more than about 200°C, due to an increase of residual austenite during a quenching process, a fatigue property of the alloy steel and the like may decrease. When the tempering time is more than about 3 hours, due to a rapid reduction in hardness of the alloy steel, it may be difficult to improve a durability life and the like.
[0065] Hereinafter, a transmission for a vehicle manufactured by using a carburizing alloy steel having improved durability according to another exemplary embodiment of the present inventive concept is described.
[0066] A transmission for a vehicle manufactured using a carburizing alloy steel having improved durability according to the present disclosure may be appropriately manufactured by a person with skill in the art with reference to a publicly known technology. In more detail, when the transmission for the vehicle is manufactured by using the carburizing alloy

steel, high strengthening of the corresponding material is achieved, and thus, through a thickness reduction, a weight reduction of about 20%, and the like, the degree of freedom in design of a vehicle may be secured and manufacturing costs may be reduced. Therefore, durability of the vehicle is increased, and a weight reduction of the vehicle is achieved, and thus fuel efficiency is increased and environmental pollution is prevented.

[Example]

[0067] Hereinafter, the present disclosure will be described in more detail through the Examples. These Examples are only for illustrating the present disclosure, and it will be obvious to those skilled in the art that the scope of the present disclosure is not interpreted to be limited by these Examples.

[0068] In order to compare physical properties of the carburizing alloy steel having improved 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.

[Table 1]

Classification	Unit	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Example 1	Example 2	Example 3	Example 4
C	wt%	0.19	0.20	0.22	0.34	0.17	0.33	0.18	0.29	0.19
Si	wt%	0.63	0.62	0.63	0.52	1.85	0.55	1.86	0.54	1.78
Mn	wt%	0.65	0.61	0.58	0.71	1.21	0.78	1.23	0.75	1.22
Cr	wt%	2.06	3.64	3.73	1.34	0.61	1.38	0.63	1.22	0.86
Ni	wt%	-	-	-	0.15	0.57	0.12	0.59	0.17	0.69
Mo	wt%	0.38	-	0.16	0.23	0.44	0.21	0.47	0.24	0.48
Nb	wt%	0.029	0.026	0.025	0.024	0.067	0.022	0.066	0.026	0.064
V	wt%	-	-	-	0.16	0.44	0.13	0.47	0.15	0.44
Ti	wt%	-	0.0018	-	0.15	0.45	0.18	0.46	0.19	0.45
B	wt%	-	0.013	-	0.000013	0.000042	0.000046	0.000026	0.000046	0.0025
N	wt%	0.0076	0.0067	0.0083	0.0067	0.0062	0.006	0.0053	0.006	0.0053
W	wt%	-	-	-	0.21	0.13	0.22	0.15	0.25	0.35
Zr	wt%	-	-	-	0.003	0.005	0.004	0.007	0.005	0.006
Co	wt%	-	-	-	5.15	-	-	-	4.92	-
Y	wt%	-	-	-	-	2.13	-	-	-	1.86

[0069] Table 1 is a table where the configuration components and the contents of Comparative Examples 1 to 3 according to the alloy steel in the related art and the configuration components and the contents of Examples 1 and 2 according to the present disclosure are compared.

[Table 2]

Classification	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Example 1	Example 2	Example 3	Example 4
Carburizing temperature (°C)/time (h)	930/3.5	940/1.65	930/1.8	930/3.5	980/2.33	930/3.5	980/2.33	930/3.5	980/2.33
Quenching oil temperature (°C)	110	110	110	80	120	80	120	80	120
Tempering temperature (°C)/time (h)	180/2.32	170/2.2	190/2.5	150/2.67	200/1.3	150/2.67	200/1.3	150/2.67	200/1.3

[0070] Table 2 is a table where among the manufacturing conditions of Comparative Examples 1 to 3 and Examples 1 and 2 having the configuration 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 the present disclosure.

[Table 3]

Classification	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Example 1	Example 2	Example 3	Example 4
Surface hardness (HV)	727	730	743	724	721	829	838	833	835
Core	496	515	512	489	505	535	528	529	529

hardness (HV)									
Tensile strength (MPa)	1072	1210	1214	1076	1215	1235	1243	1242	1237
Yield strength (MPa)	958	1081	1091	959	1083	1096	1127	1086	1129
Carburizing depth (mm)	0.71	0.73	0.72	0.70	0.71	0.78	0.79	0.79	0.78
Impact value (J)	25.9	23.8	38.7	24.9	24.8	47.6	48.8	47.8	48.6
Rotation bending strength (K)	107	115	125	117	113	151	153	152	154
Contact fatigue life (time, cycle)	4,190,000	8,470,000	9,020,000	4,090,000	8,450,000	13,600,000	14,900,000	14,200,000	14,300,000
Precipitate portion (%)	0.04	0.03	0.04	0.04	0.04	0.11	0.09	0.08	0.01
Martensite portion (%)	41	39	42	43	42	88	88	89	91

[0071] Table 3 is a table where after Comparative Examples 1 to 3 and Examples 1 and 2 having the configuration 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, contact fatigue lives, precipitate portions, and martensite portions are compared.

[0072] Surface hardness and core hardness were measured according to the KS B 0811 measurement method by using the Micro Vickers Hardness tester, and 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 the maximum flection moment of about 20 kgfm, the rotation number of about 200 to 3000 RPM, the 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.

[0073] 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 a contact fatigue test until cracks were formed in the specimen was measured under the condition of surface pressure of about 332 kg/mm^2, the lubricant temperature of about 80°C, and the lubricant amount of about 1.2 ℓ/min by using the contact fatigue experiment apparatus.

[0074] All of the surface hardnesses and the core hardnesses of Examples 1, 2, 3, and 4 were higher than those of the Comparative Examples, and the tensile strengths and the yield strengths of the Examples were higher than those of the Comparative Examples. The carburizing depths of the Examples were also larger than those of the Comparative Examples, and the impact values, rotation bending strengths, and the contact fatigue lives of the Examples were also improved as compared to those of the Comparative Examples. Further, it could be confirmed that both the precipitate and martensite portions were improved.

[0075] Therefore, it could be confirmed that in the Examples according to the present disclosure, as compared to the Comparative Examples, surface hardness was superior by about 10%, core hardness was superior by about 12%, tensile strength and yield strength were each superior by about 5%, the carburizing depth was superior by about 7%, the impact value was superior by about 52%, rotation bending strength was superior by about 24%, and the contact fatigue life was superior by about 72%.

[0076] As described above, the present disclosure has been described in relation to specific embodiments of the present disclosure, but the embodiments are only illustration and the present disclosure is not limited thereto. Embodiments described may be changed or modified by those skilled in the art to which the present disclosure pertains without departing from the scope of the invention, and various alterations and modifications are possible within the technical spirit of the invention and the equivalent scope of the claims which will be described below.

Claims

1. A carburizing alloy steel comprising:

   0.1 to 0.35 wt% of carbon (C), 0.1 to 2.0 wt% of silicon (Si), 0.1 to 1.5 wt% of manganese (Mn), 0.5 to 1.5 wt% of chromium (Cr), 0.2 to 0.5 wt% of molybdenum (Mo), more than 0 wt% and less than or equal to 0.07 wt% of niobium (Nb), 0.1 to 0.6 wt% of nickel (Ni), more than 0 wt% and less than or equal to 0.5 wt% of vanadium (V), more than 0 wt% and less than or equal to 0.5 wt% of titanium (Ti), more than 0 wt% and less than or equal to 0.015 wt% of nitrogen (N), and 0.00002 to 0.00005 wt% of boron (B), based on a total weight of an alloy steel and iron (Fe) as a main component.

2. The carburizing alloy steel of claim 1, further comprising:

   tungsten (W).

3. The carburizing alloy steel of claim 2, wherein a content of tungsten (W) is more than 0 wt% and less than or equal to 0.4 wt%

4. The carburizing alloy steel of any one of claims 1 to 3, further comprising:

   zirconium (Zr).

5. The carburizing alloy steel of claim 4, wherein a content of zirconium (Zr) is more than 0 wt% and less than or equal to 0.01 wt%.

6. The carburizing alloy steel of any one of claims 1 to 5, further comprising:

   cobalt (Co).

7. The carburizing alloy steel of claim 6, wherein a content of cobalt (Co) is more than 0 wt% and less than or equal to 5 wt%.

8. The carburizing alloy steel of any one of claims 1 to 7, further comprising:

   yttrium (Y).

9. The carburizing alloy steel of claim 8, wherein a content of yttrium (Y) is more than 0 wt% and less than or equal to 2 wt%.

10. The carburizing alloy steel of claim 1, further comprising:

    one or more of tungsten (W), zirconium (Zr), cobalt (Co), or yttrium (Y).

11. The carburizing alloy steel of claim 10, wherein a content of tungsten (W) is more than 0 wt% and less than or equal to 0.4 wt%, and/or a content of zirconium (Zr) is more than 0 wt% and less than or equal to 0.01 wt%, and/or a content of cobalt (Co) is more than 0 wt% and less than or equal to 5 wt%, and/or a content of yttrium (Y) is more than 0 wt% and less than or equal to 2 wt%.

12. A method of manufacturing a carburizing alloy steel, the method comprising:

    mixing materials of an alloy steel for carburizing an alloy steel;
    carburizing the alloy steel at 880 to 940°C for 1.5 to 2 hours;
    oil-quenching the carburized alloy steel at 80 to 120°C; and
    tempering the oil-quenched alloy steel at 170 to 200°C for 1 to 3 hours,
    wherein the carburizing alloy steel comprising: 0.1 to 0.35 wt% of carbon (C), 0.1 to 2.0 wt% of silicon (Si), 0.1 to 1.5 wt% of manganese (Mn), 0.5 to 1.5 wt% of chromium (Cr), 0.2 to 0.5 wt% of molybdenum (Mo), more than 0 wt% and less than or equal to 0.07 wt% of niobium (Nb), 0.1 to 0.6 wt% of nickel (Ni), more than 0 wt% and less than or equal to 0.5 wt% of vanadium (V), more than 0 wt% and less than or equal to 0.5 wt% of titanium

(Ti), more than 0 wt% and less than or equal to 0.015 wt% of nitrogen (N), and 0.00002 to 0.00005 wt% of boron (B), based on a total weight of the carburizing alloy steel and iron (Fe) as a main component.

13. A transmission for a vehicle manufactured by a carburizing alloy steel,
wherin the carburizing alloy steel comprising: 0.1 to 0.35 wt% of carbon (C), 0.1 to 2.0 wt% of silicon (Si), 0.1 to 1.5 wt% of manganese (Mn), 0.5 to 1.5 wt% of chromium (Cr), 0.2 to 0.5 wt% of molybdenum (Mo), more than 0 wt% and less than or equal to 0.07 wt% of niobium (Nb), 0.1 to 0.6 wt% of nickel (Ni), more than 0 wt% and less than or equal to 0.5 wt% of vanadium (V), more than 0 wt% and less than or equal to 0.5 wt% of titanium (Ti), more than 0 wt% and less than or equal to 0.015 wt% of nitrogen (N), and 0.00002 to 0.00005 wt% of boron (B), based on a total weight of the carburizing alloy steel and iron (Fe) as a main component.

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 15 18 9729

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	JP 3 551573 B2 (DAIDO STEEL CO LTD) 11 August 2004 (2004-08-11) * paragraph [0030]; claims 1, 2 *	1,12,13 2-11	INV. C21D1/18 C22C38/02 C22C38/04 C22C38/10 C22C38/14 C22C38/22 C22C38/54
X A	JP 3 954772 B2 (NIPPON STEEL CORP) 8 August 2007 (2007-08-08) * abstract; examples 1, ex. M *	1,13 2-11	
X A	JP 2014 047419 A (SANYO SPECIAL STEEL CO LTD) 17 March 2014 (2014-03-17) * paragraphs [0037], [0046]; claims 1-4; examples 2, ex. 15 *	1,12,13 2-11	
X A	JP H11 323487 A (SUMITOMO METAL IND) 26 November 1999 (1999-11-26) * abstract; claim 1 *	1-5,13 6-12	
A	US 2011/155290 A1 (MIYANISHI KEI [JP] ET AL) 30 June 2011 (2011-06-30) * paragraphs [0005], [0104]; claims 1,2 *	1-13	
A	JP 2002 309342 A (DAIDO STEEL CO LTD) 23 October 2002 (2002-10-23) * abstract; claim 1 *	1-13	TECHNICAL FIELDS SEARCHED (IPC) C21D C22C
A	US 2010/139811 A1 (KOZAWA SHUJI [JP] ET AL) 10 June 2010 (2010-06-10) * claims 1-6; table 1 *	1-13	
A	US 2013/186522 A1 (ICHIMIYA KATSUYUKI [JP] ET AL) 25 July 2013 (2013-07-25) * paragraphs [0001] - [0002,]; claims 1-4; tables 1-3 *	1-13	

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	8 September 2016	Chebeleu, Alice

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 18 9729

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-09-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 3551573 B2	11-08-2004	JP 3551573 B2	11-08-2004
		JP H0967644 A	11-03-1997
JP 3954772 B2	08-08-2007	JP 3954772 B2	08-08-2007
		JP 2001303174 A	31-10-2001
JP 2014047419 A	17-03-2014	JP 2014047419 A	17-03-2014
		KR 20150047524 A	04-05-2015
		US 2015218682 A1	06-08-2015
		WO 2014038548 A1	13-03-2014
JP H11323487 A	26-11-1999	JP 3534166 B2	07-06-2004
		JP H11323487 A	26-11-1999
US 2011155290 A1	30-06-2011	BR PI1004216 A2	23-02-2016
		CN 102131945 A	20-07-2011
		EP 2357260 A1	17-08-2011
		JP 4709944 B2	29-06-2011
		KR 20110036752 A	08-04-2011
		KR 20130119505 A	31-10-2013
		TW 201037090 A	16-10-2010
		US 2011155290 A1	30-06-2011
		WO 2010082481 A1	22-07-2010
JP 2002309342 A	23-10-2002	JP 4539804 B2	08-09-2010
		JP 2002309342 A	23-10-2002
US 2010139811 A1	10-06-2010	BR PI0807878 A2	17-06-2014
		CN 101652494 A	17-02-2010
		EP 2218799 A1	18-08-2010
		JP 5251868 B2	31-07-2013
		KR 20090121308 A	25-11-2009
		TW 200925286 A	16-06-2009
		US 2010139811 A1	10-06-2010
		WO 2009054530 A1	30-04-2009
US 2013186522 A1	25-07-2013	CN 103154293 A	12-06-2013
		CN 104630634 A	20-05-2015
		JP 5927868 B2	01-06-2016
		JP 2013082988 A	09-05-2013
		KR 20130058069 A	03-06-2013
		US 2013186522 A1	25-07-2013
		WO 2012073485 A1	07-06-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- KR 10201555104 **[0001]**