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(54) ALLOY STEEL FOR RAILWAY COUPLER

(57) The present disclosure relates to an alloy steel for a railway vehicle coupler. More particularly, the present disclosure relates to an alloy steel for a railway vehicle coupler, the alloy steel being able to meet all mechanical properties required for AAR couplers mainly used in Korea (i.e., the Republic of Korea) and China (i.e., the People's Republic of China) and mechanical properties required for CA-3 couplers mainly used in Russia (i.e., the Russian Federation) and the like, thereby enabling the railway vehicle coupler to be safely used in the railway system connecting Russia and the other Northeast Asian countries.

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Description

Technical Field

[0001] The present disclosure relates to an alloy steel for a railway vehicle coupler and, more particularly, to an alloy steel for a railway vehicle coupler, the alloy steel being able to meet all mechanical properties required for AAR couplers mainly used in Korea (i.e., the Republic of Korea) and China (i.e., the People's Republic of China) and mechanical properties required for CA-3 couplers mainly used in Russia (i.e., the Russian Federation) and the like, thereby enabling the railway vehicle coupler to be safely used in the railway system connecting Russia and the other Northeast Asian countries.

Background Art

[0002] A coupler for a railway vehicle is a very important safety component serving to transmit driving force and braking force to railroad cars. Recently, due to the necessity to lengthen railway vehicles including cars, the importance of the structural stability of the railway vehicle coupler is increasing.

[0003] Recently, the importance of the economy of Northeast Asia including Russia is increasing, and the improvement of the transportation, logistics, and connectivity of Northeast Asia is emerging as one of future growth engines.

[0004] Thus, research to the continental railway intended to connect the Korean Peninsula, China, Central Asia, Russia, and Europe is actively underway. In particular, in the case of freight cars, the Korean Peninsula and China use Association of American Railroads (AAR) couplers, while commonwealth independence states (CIS) countries and Mongolia use CA-3 couplers. It is impossible to connect these two types of couplers, due to different head shapes thereof. In addition, the materials of the two types of couplers are required to have different mechanical properties.

[0005] In this regard, technologies related to a variable coupler and a coupler adapter able to connect an AAR coupler and a CA-3 coupler having different head shapes to each other are being actively developed. However, the development of a material meeting the mechanical properties required for the two types of couplers is not sufficient.

[0006] A related-art technology for solving these problems is disclosed in Korean Patent No. 10-1931494 as an ally steel for a railway vehicle coupler. The major technical composition of this ally steel are characterized by including, as essential ingredients, carbon (C), manganese (Mn), silicon (Si), chromium (Cr), nickel (Ni), copper (Cu), molybdenum (Mo), aluminum (Al) , phosphorus (P), and sulfur (S), with the balance being iron (F) and unavoidable impurities.

[0007] That is, due to the above-described composition, the related-art ally steel has mechanical properties applicable to transcontinental trains exposed to severe climate changes. Thus, as a technical characteristic, the related-art ally steel may have the ability to reduce wear caused by climate changes and the friction between railway vehicle couplers, thereby improving durability. However, in the related-art ally steel, only whether or not criteria for "AAR M201, Gr.E" (hereinafter, referred to as "AAR M201"), i.e., the specification for the mechanical properties of AAR couplers, are met is considered. Thus, it is impossible to determine whether or not criteria for Russian national standard "GOST 22703, 20 GL" (hereinafter, referred to as "GOST 22703"), i.e., the specification for the mechanical properties of CA-3 couplers, are met.

[0008] In addition, for the continental railway exposed to severe climate changes, hardness from among the mechanical properties of couplers is significantly important in relation to cracking, wear, or the like. The related-art ally steel also has a problem in that whether or not criterion for the hardness condition from among the mechanical properties is met may not be determined.

[0009] Accordingly, there is urgent demand for the development of an alloy steel for a coupler, the alloy steel being able to meet AAR M201, i.e., the specification for the mechanical properties of AAR couplers, and GOST 22703, i.e., the specification for the mechanical properties of CA-3 couplers.

Disclosure

Technical Problem

[0010] Accordingly, the present disclosure has been made keeping in mind the above problems occurring in the prior art, and an objective of the present disclosure is to provide an alloy steel for a railway vehicle coupler, the alloy steel being able to meet both AAR M201, i.e., the specification for the mechanical properties of AAR couplers, and GOST 22703, i.e., the specification for the mechanical properties of CA-3 couplers, thereby enabling the railway vehicle coupler to be safely used in the railway system connecting Russia and the other Northeast Asian countries.

Technical Solution

[0011] In order to accomplish the above objective, the present disclosure provides an alloy steel for a railway vehicle coupler.

[0012] The alloy steel for a railway vehicle coupler may include carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), nickel (Ni), and copper (Cu) as essential ingredients, and may further include nanoparticles made from one of titanium nitride (TiN), cubic boron nitride (cBN) , aluminum oxide (Al_2O_3) , and zirconium dioxide (ZrO_2).

[0013] The alloy steel may further include molybdenum (Mo), vanadium (V), and aluminum (Al) as the essential ingredients.

[0014] In addition, the essential ingredients may include, by weight, 0.240% of C, 0.380% of Si, 1.160% of Mn, 0.014% of P, 0.006% of S, 0.250% of Cr, 0.250% of Ni, 0.030% of Cu, 0.180% of Mo, 0.020% of V, and 0.020% of Al, with the balance being iron (Fe) and impurities.

[0015] In addition, the alloy steel including the essential ingredients and the nanoparticles may be first heat-treated at 870°C for 4 hours, followed by air cooling, be second heat-treated at 870°C for 4 hours, followed by water cooling, and be third heat-treated at 570°C for 4 hours, followed by air cooling.

[0016] In addition, from among the essential ingredients, Ni may have a content ranging from 0.25% to 0.30% by weight, Mo may have a content ranging from 0.15% to 0.25% by weight, and V may have a content ranging from 0.01% to 0.02% by weight.

[0017] The essential ingredients may include, by weight, 0.233% of C, 0.427% of Si, 1.222% of Mn, 0.006% of P, 0.012% of S, 0.261% of Cr, 0.260% of Ni, 0.042% of Cu, 0.175% of Mo, 0.019% of V, and 0.022% of Al, with the balance being Fe, impurities, and the nanoparticles.

[0018] According to another embodiment, provided is an alloy steel for a railway vehicle coupler.

[0019] The alloy steel may include carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), nickel (Ni), and copper (Cu) as essential ingredients, and may further include nanoparticles made from one of magnesium oxide (MgO) or a material combination of, by weight, 99% of silicon oxide (SiO_2) and 1% of silicon carbide (SiC).

[0020] The alloy steel may further include molybdenum (Mo), vanadium (V), and aluminum (Al) as the essential ingredients.

[0021] In addition, the essential ingredients may include, by weight, 0.240% of C, 0.380% of Si, 1.160% of Mn, 0.014% of P, 0.006% of S, 0.250% of Cr, 0.250% of Ni, 0.030% of Cu, 0.180% of Mo, 0.020% of V, and 0.020% of Al, with the balance being iron (Fe), impurities, and the nanoparticles.

[0022] In addition, the alloy steel including the essential ingredients and the nanoparticles may be first heat-treated at 870°C for 4 hours, followed by air cooling, be second heat-treated at 870°C for 4 hours, followed by water cooling, and be third heat-treated at 580°C for 4 hours, followed by air cooling.

[0023] In addition, the essential ingredients may include, by weight, 0.220% of C, 0.430% of Si, 1.200% of Mn, 0.016% of P, 0.006% of S, 0.260% of Cr, 0.250% of Ni, 0.030% of Cu, 0.150% of Mo, 0.020% of V, and 0.030% of Al, with the balance being iron (Fe), impurities, and the nanoparticles.

[0024] In addition, the alloy steel including the essential ingredients and the nanoparticles may be heat-treated at 580°C for 4 hours, followed by air cooling.

Advantageous Effects

[0025] According to the present disclosure, the nanoparticles able to reduce the hardness of the alloy steel and the nanoparticles able to improve the strength of the alloy steel to the alloy steel for a railway vehicle coupler are selectively added to the alloy steel for a railway vehicle coupler according to the present disclosure as described above includes, in addition to the ingredients included as essential ingredients in AAR couplers and CA-3 couplers, thereby having an excellent effect in that both the specification for the mechanical properties of AAR couplers and the specification for the mechanical properties of CA-3 couplers may be meet.

[0026] In addition, according to the present disclosure, the alloy steel may meet mechanical property criteria for the two types of couplers most widely used in the world. Advantageously, the alloy steel according to the present disclosure may be compatibly used in most countries in the world and be safely used in the railway system currently in progress to connect Russia and the other Northeast Asian countries.

Best Mode

[0027] Hereinafter, exemplary embodiments of an alloy steel for a railway vehicle coupler according to the present disclosure will be described in detail.

[0028] The present disclosure relates to an alloy steel for a railway vehicle coupler and, more particularly, to an alloy steel for a railway vehicle coupler, the alloy steel enabling a railway vehicle coupler to meet all mechanical properties required for AAR couplers mainly used in Korea (i.e., the Republic of Korea) and China (i.e., the People's Republic of China) and mechanical properties required for CA-3 couplers mainly used in Russia (i.e., the Russian Federation) and the like, thereby enabling railway vehicle couplers made from the alloy steel to be safely used in railway systems connecting Russia and the other Northeast Asian countries. First, the specification of AAR M201 specifying mechanical properties required for AAR couplers and the specification of GOST 22703 specifying mechanical properties required for CA-3 couplers are as illustrated in Table 1 below. The contents of chemical ingredients in Table 1 below are indicated in weight percent.

Table 1

Classification		AAR M201 SPEC	GOST 22703 SPEC	SPEC of Common Material to be Developed
Chem. Comp.*1	C	Max 0.32	0.17~0.25	0.17~0.25
	Si	Max 1.50	0.30~0.50	0.30~0.50
	Mn	Max 1.85	1.10~1.40	1.10~1.40
	P	Max 0.04	Max 0.04	Max 0.04
	S	Max 0.04	Max 0.04	Max 0.04
	Cr		Max 0.30	Max 0.30
	Ni		Max 0.30	Max 0.30
	Mo			-
	V			-
	Cu		Max 0.30	Max 0.30
	Al			-
Mech. Props*2	Y/P (N/mm^2)	Min 689.0	Min 500.0	Min 689.0
	T/S (N/mm^2)	Min 826.8	Min 600.0	Min 826.8
	El (%)	Min 14	Min 12	Min 14
	R/A (%)	Min 30	Min 25	Min 30
	Impact Strength (J)	KCV (-40°C) Min 27	KCV (-60°C) Min 15	KCV (-60°C) Min 15
	HB	241~311	192~262	241~262

Note)

*1: Chemical Composition

*2: Mechanical Properties

[0029] As illustrated in Table 1 above, it may be found that the AAR M201 standard regarding the chemical composition of the coupler is not strict and only specifies maximum values of carbon (C), silicon (Si), manganese (Mn), phosphorus (P), and sulfur (S). In contrast, the GOST 22703 standard regarding the chemical composition of the coupler is relatively strict to further specify the maximum values of chromium (Cr), nickel (Ni), and copper (Cu) and define the content ranges of C, Si, and Mn.

[0030] The AAR M201 standard and the GOST 22703 standard also have different specifications about mechanical properties. In Russia where the GOST 22703 standard are applied, railway vehicles must be able to operate in an environment having a relatively low temperature. Thus, it may be found that requirements for yield strength (Y/P), tensile strength (T/S), and hardness (HB) are relatively low and impact strength at -60°C is further required for cold resistance.

[0031] Since the objective of the present disclosure is to meet the chemical ingredients, i.e., the chemical composition, and the mechanical properties required by the AAR M201 standard and the GOST 22703 standard, the present disclosure may meet the chemical composition and the mechanical properties illustrated in the rightmost column of Table 1 above.

[0032] Described in more detail, the alloy steel for a railway vehicle coupler according to the present disclosure is provided as an alloy steel including the chemical ingredients required by the AAR M201 standard and the GOST 22703 standard, i.e., carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), nickel (Ni), and copper (Cu) as essential ingredients. The alloy steel is characterized by further including nanoparticles made from one of titanium nitride (TiN), cubic boron nitride (cBN), aluminum oxide (Al_2O_3) , and zirconium dioxide (ZrO_2) .

[0033] TiN, cBN, Al_2O_3, and ZrO_2 described above may be included in the alloy steel to reduce the hardness thereof, and may be included in the alloy steel as nanoparticles to obtain a hardness reduction effect even if in a minute amount.

[0034] That is, according to test results, it was possible to easily meet target conditions for some mechanical properties, such as the elongation El, the reduction of area R/A, and impact strength, from among the target conditions for the mechanical properties illustrated in the rightmost column of Table 1 above by adjusting the contents of C, Si, Mn, P, S, Cr, Ni, and Cu. However, there have been limitations in meeting the target conditions for the remaining mechanical properties, i.e., the yield strength Y/P, the tensile strength T/S, and the hardness HB, by adjusting the contents of the essential ingredients.

[0035] Described in more detail, there has been a problem in that, when the target conditions for the yield strength Y/P and the tensile strength T/S of the alloy steel were met, the hardness HB exceeded the target condition, and when the target condition for the hardness HB of the alloy steel was met, either the target condition for the yield strength Y/P or the target condition for the tensile strength T/S was met.

[0036] Thus, nanoparticles made of one from among TiN, cBN, Al_2O_3, and ZrO_2 may be included in the alloy steel so as to reduce the hardness HB of the alloy steel while minimizing changes in the yield strength Y/P and the tensile strength T/S of the alloy steel.

[0037] Table 2 below illustrates test results regarding hardness changes in the alloy steel with the hardness HB of 203 when TiN nanoparticles and cBN nanoparticles were added to the alloy steel. It may be found that the hardness HB was reduced by 3.94% and 6.4%, respectively, in response to the addition of the TiN nanoparticles and the cBN nanoparticles.

Table 2

Nanoparticle Additive	Not Added	Titanium Nitride (TiN)	Boron Nitride (cBN)
hardness HB	203	195	190

[0038] In addition, in a similar test, it was found that the Al_2O_3 nanoparticles and the ZrO_2 nanoparticles were able to reduce the hardness by 27% and 38%, respectively. Thus, according to the magnitude of the hardness of the alloy steel to be reduced, one from among TiN, cBN, Al_2O_3, and ZrO_2 may be selected so as to be included in the alloy steel as nanoparticles.

[0039] In addition, in an alloy steel for a railway vehicle coupler according to another embodiment of the present disclosure, nanoparticles included in the alloy steel including essential ingredients may be made from one of magnesium oxide (MgO) or a material combination of, by weight, 99% of silicon oxide (SiO_2) and 1% of silicon carbide (SiC). These two materials are used in a situation in which either the yield strength Y/P or the tensile strength T/S of the alloy steel does not meet the target condition while the target condition for the hardness HB of the alloy steel is met.

[0040] That is, MgO and the material combination of, by weight, 99% of SiO_2 and 1% of SiC is used in order to improve the strength of the alloy steel. When these materials are included in the alloy steel even in a very small amount, the effect of improved strength may be obtained.

[0041] Described in more detail, when MgO nanoparticles are added to a carbon steel, it an improvement effect of the yield strength Y/P by about 22.4% and an improvement effect of the tensile strength T/S by about 53.1% may be obtained according to the amount of nanoparticles input, as may be found from Table 3 below.

Table 3

Mass Fraction (%) of MgO Nanoparticles	0	0.01	0.03	0.05	0.07
Yield Strength (MPa)	232	233	264	294	284
Tensile Strength (MPa)	293	425	427	448	441

[0042] In addition, when nanoparticles made from the material combination of, by weight, 99% of SiO_2 and 1% of SiC are added to the carbon steel, a strength improvement effect of up to about 60% may be obtained without a significant change in the hardness HB, as may be found from Table 4 below.

Table 4

Modifier Weight (g)	0	77	120	460
Hardness HB	185-210	210	220	190
Strength (MPa)	168-180	270	240	200

[0043] As described above, in the present disclosure, it is possible to reduce the hardness HB of the alloy steel including C, Si, Mn, P, S, Cr, Ni, and Cu or improve the strength, i.e., the yield strength Y/P and the tensile strength T/S, of the alloy steel by adding nanoparticles to the steel alloy. When intended to reduce the hardness HB, nanoparticles made from one from among TiN, cBN, Al_2O_3, and ZrO_2 are added to the alloy steel. When intended to improve the strength, nanoparticles made from one of MgO and the material combination of, by weight, 99% of SiO_2 and 1% of SiC are added to the alloy steel. In addition, first specimens cast from a material including chemical ingredients meeting both the AAR M201 standard and the GOST 22703 standard described above were heat-treated in different heat treatment conditions, and then, the mechanical properties thereof were tested. The results of the test are illustrated in Table 5 below.

Table 5

Classification		SPEC to be Developed	Test Result of Korea Railroad Research Institute	
			1st Specimen, 1st time	2nd Specimen, 2nd time
Chem. Comp.*1	C	0.17~0.25	0.226	0.226
	Si	0.30~0.50	0.472	0.472
	Mn	1.10~1.40	1.227	1.227
	P	Max 0.04	0.006	0.006
	S	Max 0.04	0.014	0.014
	Cr	Max 0.30	0.244	0.244
	Ni	Max 0.30	0.240	0.240
	Mo	-	0.026	0.026
	V	-	0.001	0.001
	Cu	Max 0.30	0.037	0.037
	Al	-	0.024	0.024
Mech. Props*2	Y/P (N/mm^2)	Min 689.0	438.0	684.0
	T/S (N/mm^2)	Min 826.8	726.0	872.0
	El (%)	Min 14	8.0	17.2
	R/A (%)	Min 30	15.4	45.0
	Impact Strength (J)	KCV (-60°C) Min 15	19.7	10.9
	HB	241~262	235	255

Note)

*1: Chemical Composition

*2: Mechanical Properties

[0044] Although the tensile strength T/S, the elongation (El) , the reduction of area R/A, and the hardness HB were improved to meet target conditions for mechanical properties, it may be found that the yield strength Y/P and the impact strength were less than the target values.

[0045] In addition, the alloy steel for a railway vehicle coupler according to the present disclosure may further include molybdenum (Mo), vanadium (V), and aluminum (Al), in addition to the above-described essential ingredients. First, Al is typically included in the alloy steel and is used to improve the ductility of the alloy steel.

[0046] Next, Mo is added to improve the impact strength, i.e., sock absorption rate, of the alloy steel. This feature may be found from Table 6 below.

[0047] That is, Table 6 below illustrates results obtained by heat-treating second specimens cast from a material further including Mo, in addition to the chemical ingredients meeting both the AAR M201 standard and the GOST 22703 standard, in different heat treatment conditions, and then, testing the mechanical properties of the second specimens. It was found that, when the heat treatment was performed so that the hardness HB is within the target range, most mechanical properties met the target ranges.

[0048] In particular, it may be found that, while the impact strength was improved twice or more by the addition of Mo, the yield strength Y/P and the tensile strength T/S were reduced so that the tensile strength T/S did not meet the target value.

Table 6

Classification		SPEC to be Developed	Test Result of Korea Railroad Research Institute	
			2nd Specimen, 1st time	2nd Specimen, 2nd time
Chem. Comp.*1	C	0.17~0.25	0.243	0.243
	Si	0.30~0.50	0.482	0.482
	Mn	1.10~1.40	1.271	1.271
	P	Max 0.04	0.011	0.011
	S	Max 0.04	0.012	0.012
	Cr	Max 0.30	0.297	0.297
	Ni	Max 0.30	0.288	0.288
	Mo	-	0.194	0.194
	V	-	0.001	0.001
	Cu	Max 0.30	0.044	0.044
	Al	-	0.025	0.025
Mech. Props*2	Y/P (N/mm^2)	Min 689.0	866.0	706.0
	T/S (N/mm^2)	Min 826.8	954.0	812.0
	El (%)	Min 14	13.2	16.0
	R/A (%)	Min 30	33.3	48.5
	Impact Strength (J)	KCV (-60°C) Min 15	21.8	26.3
	HB	241~262	285	255

Note)

*1: Chemical Composition

*2: Mechanical Properties

[0049] Next, V is added to improve the strength of the alloy steel, and this feature may be found from Table 7 below.

[0050] That is, Table 7 below illustrates results obtained by heat-treating third specimens cast from a material further including Mo and V, in addition to the chemical ingredients meeting both the AAR M201 standard and the GOST 22703 standard, in different heat treatment conditions, and then, testing the mechanical properties of the second specimens. It may be found that, while the yield strength Y/P and the tensile strength T/S were improved to meet the target values by the addition of V, the hardness HB was also improved proportionally to exceed the target value and the impact strength was reduced, thereby failing to meet the target value.

Table 7

Classification		SPEC to be Developed	Test Result of Korea Railroad Research Institute	
			3rd Specimen, 1st time	3rd Specimen, 2nd time
Chem. Comp.*1	C	0.17~0.25	0.222	0.222
	Si	0.30~0.50	0.496	0.496
	Mn	1.10~1.40	1.228	1.228
	P	Max 0.04	0.012	0.012
	S	Max 0.04	0.013	0.013
	Cr	Max 0.30	0.240	0.240
	Ni	Max 0.30	0.168	0.168
	Mo	-	0.213	0.213
	V	-	0.052	0.052
	Cu	Max 0.30	0.035	0.035
	Al	-	0.027	0.027
Mech. Props*2	Y/P (N/mm^2)	Min 689.0	811.0	748.0
	T/S (N/mm^2)	Min 826.8	905.0	842.0
	El (%)	Min 14	15.6	15.0
	R/A (%)	Min 30	38.5	43.5
	Impact Strength (J)	KCV (-60°C) Min 15	10.1	9.5
	HB	241~262	285	269

Note)

*1: Chemical Composition

*2: Mechanical Properties

[0051] According to the results of the tests described above, it may be found that the impact strength was improved by adding Mo to the specified essential ingredients of the alloy steel and the yield strength Y/P and the tensile strength T/S were improved by adding V to the essential ingredients.

[0052] However, in the case of Mo, the yield strength Y/P and the tensile strength T/S were reduced by the heat treatment intended to meet the range of the hardness HB. When V was added to solve the reduction, the impact strength was also reduced. Thus, in order to overcome these problems, it is necessary to limit the contents of Mo and V.

[0053] Accordingly, fourth and fifth specimens cast by limiting the contents of Mo and V to, by weight, 0.15% to 0.25% and 0.01% to 0.02% and setting the content of Ni having superior impact strength, from among the essential ingredients specified in the AAR M201 standard and the GOST 22703 standard, to 0.25% to 0.30% by weight were heat-treated in different heat treatment conditions, and then, mechanical properties thereof were tested. The results of the test are illustrated in Table 8 below.

Table 8

Classification		SPEC to be Developed	Test Result of Korea Railroad Research Institute	
			4th Specimen	5th Specimen
Chem. Comp.*1	C	0.17~0.25	0.24	0.233
	Si	0.30~0.50	0.38	0.427
	Mn	1.10~1.40	1.16	1.222
	P	Max 0.04	0.014	0.006
	S	Max 0.04	0.006	0.012
	Cr	Max 0.30	0.25	0.261
	Ni	Max 0.30	0.25	0.260
	Mo	-	0.18	0.175
	V	-	0.02	0.019
	Cu	Max 0.30	0.03	0.042
	Al	-	0.02	0.022
Mech. Props*2	Y/P (N/mm^2)	Min 689.0	724.0	825.6
	T/S (N/mm^2)	Min 826.8	932.0	939.8
	El (%)	Min 14	16.0	16.0
	R/A (%)	Min 30	44.0	48.16
	Impact Strength (J)	KCV (-60°C) Min 15	23.3	22.5
	HB	241~262	291	277

Note)

*1: Chemical Composition

*2: Mechanical Properties

[0054] First, the fourth specimen was cast by limiting the contents of Ni, Mo, and V to 0.25%, 0.18%, 0.02% by weight, respectively, while meeting the contents of the essential ingredients specified in the AAR M201 standard and the GOST 22703 standard, followed by heat treatment. It may be found that the fourth specimen met the target values for all mechanical properties, except for the hardness HB.

[0055] Next, the fifth specimen was cast by limiting the contents of Ni, Mo, and V to 0.260%, 0.175%, and 0.019% by weight, while meeting the contents of the essential ingredients specified in the AAR M201 standard and the GOST 22703 standard, followed by heat treatment. It may also be found that the fifth specimen met the target values for all mechanical properties, except for the hardness HB.

[0056] That is, it was found that both the fourth specimen and the fifth specimen met the target conditions for all mechanical properties, i.e., the yield strength Y/P, the tensile strength T/S, the elongation (El), the reduction of area

R/A, and the impact strength, except for the hardness HB. As described above, the hardness HB may be reduced by the addition of nanoparticles made from one of TiN, cBN, Al_2O_3, and ZrO_2. Thus, it is possible to manufacture a carbon steel having mechanical properties meeting both the AAR M201 standard and the GOST 22703 standard by adding the nanoparticles.

[0057] In addition, the mechanical properties of the above-described alloy steel for a railway vehicle coupler according to the present disclosure may be changed according to heat treatment conditions. Table 9 below illustrates test results for the mechanical properties of alloy steel specimens having the same composition as the fourth specimen illustrated in Table 8, tested two times by the Korea Testing and Research Institute (KTR) and the Korea Railroad Research Institute (KRRI), and test results for the mechanical properties of alloy steel specimens respectively having a new composition of, by weight, 0.220% of C, 0.430% of Si, 1.200% of Mn, 0.016% of P, 0.006% of S, 0.260% of Cr, 0.250% of Ni, 0.030% of Cu, 0.150% of Mo, 0.020% of V, and 0.030% of Al, tested by the KTR, together with heat treatment conditions.

Table 9

Classification		SPEC to be Developed	Test Result of KTR		Test Result of KRRI		Test Result of KTR
			1st	2nd	1st	2nd	
Chem. Comp. *1	C	0.17~0.25	0.240		0.240		0.220
	Si	0.30~0.50	0.380		0.380		0.430
	Mn	1.10~1.40	1.160		1.160		1.200
	P	Max 0.04	0.014		0.014		0.016
	S	Max 0.04	0.006		0.006		0.006
	Cr	Max 0.30	0.250		0.250		0.260
	Ni	Max 0.30	0.250		0.250		0.250
	Mo	-	0.180		0.180		0.150
	V	-	0.020		0.020		0.020
	Cu	Max 0.30	0.030		0.030		0.030
	Al	-	0.020		0.020		0.030
Mech. Props *2	Y/P (N/mm^2)	Min 689.0	780	667	763	774.1	646

T/S (N/mm^2)	Min 826.8	899	836	861	878	793
El (%)	Min 14	19	16	14.6	23	18
R/A (%)	Min 30	46	38	33.69	60.49	53
IS*3 (J)	KCV (-60°C) Min 15	39/43	28/27	-	-	30/26
HB	241~262	271	256	269	275	252
1st H*4		870°C, 4 Hrs; Air Cooling	870°C, 4 Hrs; Air Cooling	870°C, 4 Hrs; Air Cooling	870°C, 4 Hrs; Air Cooling	
2nd HT*5		870°C, 4 Hrs, Water Cooling	870°C, 4 Hrs, Water Cooling	870°C, 4 Hrs, Water Cooling	870°C, 4 Hrs, Water Cooling	
3rd HT*6		570°C, 4 Hrs; Air Cooling	580°C, 4 Hrs; Air Cooling	570°C, 4 Hrs; Air Cooling	580°C, 4 Hrs; Air Cooling	580°C, 4 Hrs; Air Cooling

Note)

*1: Chemical Composition

*2: Mechanical Properties

*3: Impact Strength

*4: Heat Treatment (Normalizing)

*5: Heat Treatment (Quenching)

*6: Heat Treatment (Tempering)

[0058] First, in alloy steel specimens having the same composition as the fourth specimen, i.e., the composition including, by weight, 0.240% of C, 0.380% of Si, 1.160% of Mn, 0.014% of P, 0.006% of S, 0.250% of Cr, 0.250% of Ni, 0.030% of Cu, 0.180% of Mo, 0.020% of V, and 0.020% of Al, a total of three heat treatments was performed. In the first test by the KTR and the first and second tests by the KRRI, the heat treatments were performed in the same conditions. In the second test by the KTR, the heat treatment was performed by changing the temperature conditions of the third heat treatment.

[0059] Described in more detail, in the first test by the KTR and the first and second tests by the KRRI, the first heat treatment corresponding to normalizing was performed at 870°C for 4 hours, followed by air cooling. In the second heat treatment corresponding to quenching, the heat treatment was performed at 870°C for 4 hours in the same manner as above, followed by water cooling. In the third heat treatment corresponding to tempering, the heat treatment was performed at 570°C for 4 hours, followed by air cooling. Afterwards, the mechanical properties of the specimens were measured.

[0060] As a result, it was found that all mechanical properties except for the hardness HB, i.e., the yield strength Y/P, the tensile strength T/S, the elongation (El), the reduction of area R/A, and the impact strength, were met in the three tests. In the first test by the KTR, the hardness HB was measured to exceed the target range by about 3.4%. in the first and second tests by the KRRI, the hardness HB was measured to exceed the target range by about 2.7% and about 5.0%.

[0061] It was found from Table 2 above that the hardness HB might be reduced by 3.94% and 6.4% by the addition of the TiN nanoparticles and the boron nitride (cBN) nanoparticles, respectively. Thus, when one of the TiN nanoparticles and the boron nitride (cBN) nanoparticles is selectively added to the alloy steel including, by weight, 0.240% of C, 0.380% of Si, 1.160% of Mn, 0.014% of P, 0.006% of S, 0.250% of Cr, 0.250% of Ni, 0.030% of Cu, 0.180% of Mo, 0.020% of V, and 0.020% of Al, an alloy steel for a railway vehicle coupler able to meet the target conditions for all mechanical properties including the hardness HB condition may be manufactured.

[0062] In addition, in the second test by the KTR for the alloy steel having the same composition as above, the heat treatment was performed in the same conditions as the foregoing three heat treatments, except for varying the temperature of the third heat treatment corresponding to tempering to be 580°C, and then, the mechanical properties thereof were measured.

[0063] As a result, it was found that the target conditions for all mechanical properties except for the yield strength Y/P were met. The yield strength Y/P was determined to be less than the target value by about 3.2%.

[0064] It was found from Table 3 and Table 4 above that the yield strength Y/P may be improved by the addition of the MgO nanoparticles or the nanoparticles made from the material combination of, by weight, 99% of SiO_2 and 1% of SiC. In a situation in which the temperature of the third heat treatment is 580°C, when one of the MgO nanoparticles and the nanoparticles made from the material combination of, by weight, 99% of SiO_2 and 1% of SiC is selectively added to the alloy steel, an alloy steel for a railway vehicle coupler able to meet the target conditions for all mechanical properties except for the yield strength Y/P may be manufactured.

[0065] Next, in the alloy steel including, by weight, 0.220% of C, 0.430% of Si, 1.200% of Mn, 0.016% of P, 0.006% of S, 0.260% of Cr, 0.250% of Ni, 0.030% of Cu, 0.150% of Mo, 0.020% of V, and 0.030% of Al, the mechanical properties thereof were measured after the heat treatment corresponding to tempering was performed in order to reduce a heat treatment time and prevent the hardness HB from exceeding the target range. The heat treatment was performed at a temperature of 580°C for 4 hours, followed by air cooling.

[0066] As a result, it was found that the target conditions for the mechanical properties except for the yield strength Y/P and the tensile strength T/S were met. The yield strength Y/P and the tensile strength T/S were determined to be less than the target values by about 6.2% and about 4.1%, respectively.

[0067] As described above, when the MgO nanoparticles or the nanoparticles made from the material combination of, by weight, 99% of SiO_2 and 1% of SiC are added to the alloy steel, the yield strength Y/P and the tensile strength T/S may be improved without a significant change in the hardness HB. Thus, Thus, by heat-treating the alloy steel including, by weight, 0.220% of C, 0.430% of Si, 1.200% of Mn, 0.016% of P, 0.006% of S, 0.260% of Cr, 0.250% of Ni, 0.030% of Cu, 0.150% of Mo, 0.020% of V, and 0.030% of Al, and further including the MgO nanoparticles or the nanoparticles made from the material combination of, by weight, 99% of SiO_2 and 1% of SiC, at a temperature of 580°C for 4 hours, an alloy steel for a railway vehicle coupler able to meet the target conditions for all mechanical properties including the yield strength Y/P and the tensile strength T/S may be manufactured.

[0068] Accordingly, since the nanoparticles able to reduce the hardness of the alloy steel and the nanoparticles able to improve the strength of the alloy steel to the alloy steel for a railway vehicle coupler are selectively added to the alloy steel for a railway vehicle coupler according to the present disclosure as described above, in addition to the ingredients included as essential ingredients in AAR couplers and CA-3 couplers, both the specification for the mechanical properties of AAR couplers and the specification for the mechanical properties of CA-3 couplers may be meet. Thus, the alloy steel according to the present disclosure may meet mechanical property criteria for the two types of couplers most widely used in the world. Advantageously, the alloy steel according to the present disclosure may be compatibly used in most countries in the world and be safely used in the railway system currently in progress to connect Russia and the other Northeast Asian countries.

[0069] Although the foregoing embodiments have been described with respect to most exemplary examples of the present disclosure, it will be apparent to those skilled in the art that the present disclosure is not limited thereto and a variety of modifications is possible without departing from the technical principle of the present disclosure.

Industrial Applicability

[0070] The present disclosure relates to an alloy steel for a railway vehicle coupler. More particularly, the present disclosure relates to an alloy steel for a railway vehicle coupler, the alloy steel being able to meet all mechanical properties required for AAR couplers mainly used in Korea (i.e., the Republic of Korea) and China (i.e., the People's Republic of China) and mechanical properties required for CA-3 couplers mainly used in Russia (i.e., the Russian Federation) and the like, thereby enabling the railway vehicle coupler to be safely used in the railway system connecting Russia and the other Northeast Asian countries.

Claims

1. An alloy steel for a railway vehicle coupler, the alloy steel comprising carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), nickel (Ni), and copper (Cu) as essential ingredients,
the alloy steel further comprising nanoparticles made from one of titanium nitride (TiN), cubic boron nitride (cBN), aluminum oxide (Al_2O_3), and zirconium dioxide (ZrO_2).

2. The alloy steel according to claim 1, further comprising molybdenum (Mo), vanadium (V), and aluminum (Al) as the essential ingredients.

3. The alloy steel according to claim 2, wherein the essential ingredients include, by weight, 0.240% of C, 0.380% of Si, 1.160% of Mn, 0.014% of P, 0.006% of S, 0.250% of Cr, 0.250% of Ni, 0.030% of Cu, 0.180% of Mo, 0.020% of V, and 0.020% of Al, with the balance being iron (Fe) and impurities.

4. The alloy steel according to claim 3, wherein the alloy steel comprising the essential ingredients and the nanoparticles is first heat-treated at 870°C for 4 hours, followed by air cooling, is second heat-treated at 870°C for 4 hours, followed by water cooling, and is third heat-treated at 570°C for 4 hours, followed by air cooling.

5. The alloy steel according to claim 2, wherein, from among the essential ingredients, Ni has a content ranging from 0.25% to 0.30% by weight, Mo has a content ranging from 0.15% to 0.25% by weight, and V has a content ranging from 0.01% to 0.02% by weight.

6. The alloy steel according to claim 5, wherein the essential ingredients include, by weight, 0.233% of C, 0.427% of Si, 1.222% of Mn, 0.006% of P, 0.012% of S, 0.261% of Cr, 0.260% of Ni, 0.042% of Cu, 0.175% of Mo, 0.019% of V, and 0.022% of Al, with the balance being Fe, impurities, and the nanoparticles.

7. An alloy steel for a railway vehicle coupler, the alloy steel comprising carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), nickel (Ni), and copper (Cu) as essential ingredients,
the alloy steel further comprising nanoparticles made from one of magnesium oxide (MgO) or a material combination of, by weight, 99% of silicon oxide (SiO_2) and 1% of silicon carbide (SiC) .

8. The alloy steel according to claim 7, further comprising molybdenum (Mo), vanadium (V), and aluminum (Al) as the essential ingredients.

9. The alloy steel according to claim 8, wherein the essential ingredients include, by weight, 0.240% of C, 0.380% of Si, 1.160% of Mn, 0.014% of P, 0.006% of S, 0.250% of Cr, 0.250% of Ni, 0.030% of Cu, 0.180% of Mo, 0.020% of V, and 0.020% of Al, with the balance being iron (Fe), impurities, and the nanoparticles.

10. The alloy steel according to claim 9, wherein the alloy steel comprising the essential ingredients and the nanoparticles is first heat-treated at 870°C for 4 hours, followed by air cooling, is second heat-treated at 870°C for 4 hours, followed by water cooling, and is third heat-treated at 580°C for 4 hours, followed by air cooling.

11. The alloy steel according to claim 8, wherein the essential ingredients include, by weight, 0.220% of C, 0.430% of Si, 1.200% of Mn, 0.016% of P, 0.006% of S, 0.260% of Cr, 0.250% of Ni, 0.030% of Cu, 0.150% of Mo, 0.020% of V, and 0.030% of Al, with the balance being iron (Fe), impurities, and the nanoparticles.

12. The alloy steel according to claim 11, wherein the alloy steel comprising the essential ingredients and the nanoparticles is heat-treated at 580°C for 4 hours, followed by air cooling.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2020/018300

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/42(2006.01)i; **C22C 1/05**(2006.01)i; **C22C 38/44**(2006.01)i; **C22C 38/46**(2006.01)i; **C22C 38/60**(2006.01)i; **B61G 1/00**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/42(2006.01); B21B 3/00(2006.01); C21C 7/10(2006.01); C21D 8/02(2006.01); C21D 9/04(2006.01); C22C 38/00(2006.01); C22C 38/14(2006.01); C22C 38/24(2006.01); C22C 38/44(2006.01); C22C 38/50(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 탄소(carbon), 나노입자(nanoparticle), 철도(railway), 질화티탄(TiN), 산화마그네슘(MgO)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2002-363702 A (NIPPON STEEL CORP.) 18 December 2002 (2002-12-18) See paragraphs [0008], [0014] and [0059] and claims 1, 7-8, 10, 13-14 and 16.	1-2,5,7-8
A		3-4,6,9-12
A	KR 10-1499868 B1 (LEE, Tae-Young) 12 March 2015 (2015-03-12) See paragraphs [0040]-[0053] and claim 1.	1-12
A	CN 102534416 A (LAIWU IRON & STEEL GROUP CO., LTD. et al.) 04 July 2012 (2012-07-04) See paragraph [0017] and claim 1.	1-12
A	JP 2005-002385 A (SUMITOMO METAL IND. LTD.) 06 January 2005 (2005-01-06) See paragraph [0032] and claims 1 and 3.	1-12
A	US 5482576 A (HELLER et al.) 09 January 1996 (1996-01-09) See claims 1 and 6.	1-12

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 April 2021	**07 April 2021**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2020/018300

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