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(54) Titre : TOLE D'ACIER BASSE TEMPERATURE AYANT UNE EXCELLENTE QUALITE DE TRAITEMENT DE SURFACE ET PROCEDE POUR LA FABRIQUER
(54) Title: STEEL SHEET FOR LOW-TEMPERATURE SERVICE HAVING EXCELLENT SURFACE PROCESSING QUALITY AND METHOD FOR MANUFACTURING SAME

【FIG. 1A】

(57) Abrégé/Abstract:
The present invention relates to a steel sheet for low-temperature service, which can be used at a wide temperature range from low temperature to room temperature in liquefied gas storage tanks and transport facilities, and provides: a steel sheet for low-

(57) Abrégé(suite)/Abstract(continued):
temperature service having an excellent surface processing quality even after a processing processes is performed, such as a tension process; and a method for manufacturing the same. An aspect of the present invention relates to a steel sheet for low-temperature service having an excellent surface processing quality, the steel sheet for low-temperature service containing manganese (Mn, 15-35 wt%), carbon (C, satisfying $23.6C + Mn \geq 28$ and $33.5C - Mn \leq 23$), copper (Cu, 5 wt% or less (excluding 0 wt%)), chrome (Cr, satisfying $28.5C + 4.4Cr \leq 57$ (excluding 0 wt%)), titanium (Ti, 0.01-0.5 wt%), nitrogen (N, 0.003-0.2 wt%), the balance iron (Fe), and other inevitable impurities, wherein Ti and N satisfy relational expression 1 below. [Relational expression 1] $1.0 \leq Ti/N \leq 4.5$ (provided that, Mn, C, Cr, Ti, and N in the respective expressions mean wt% of respective ingredient contents).

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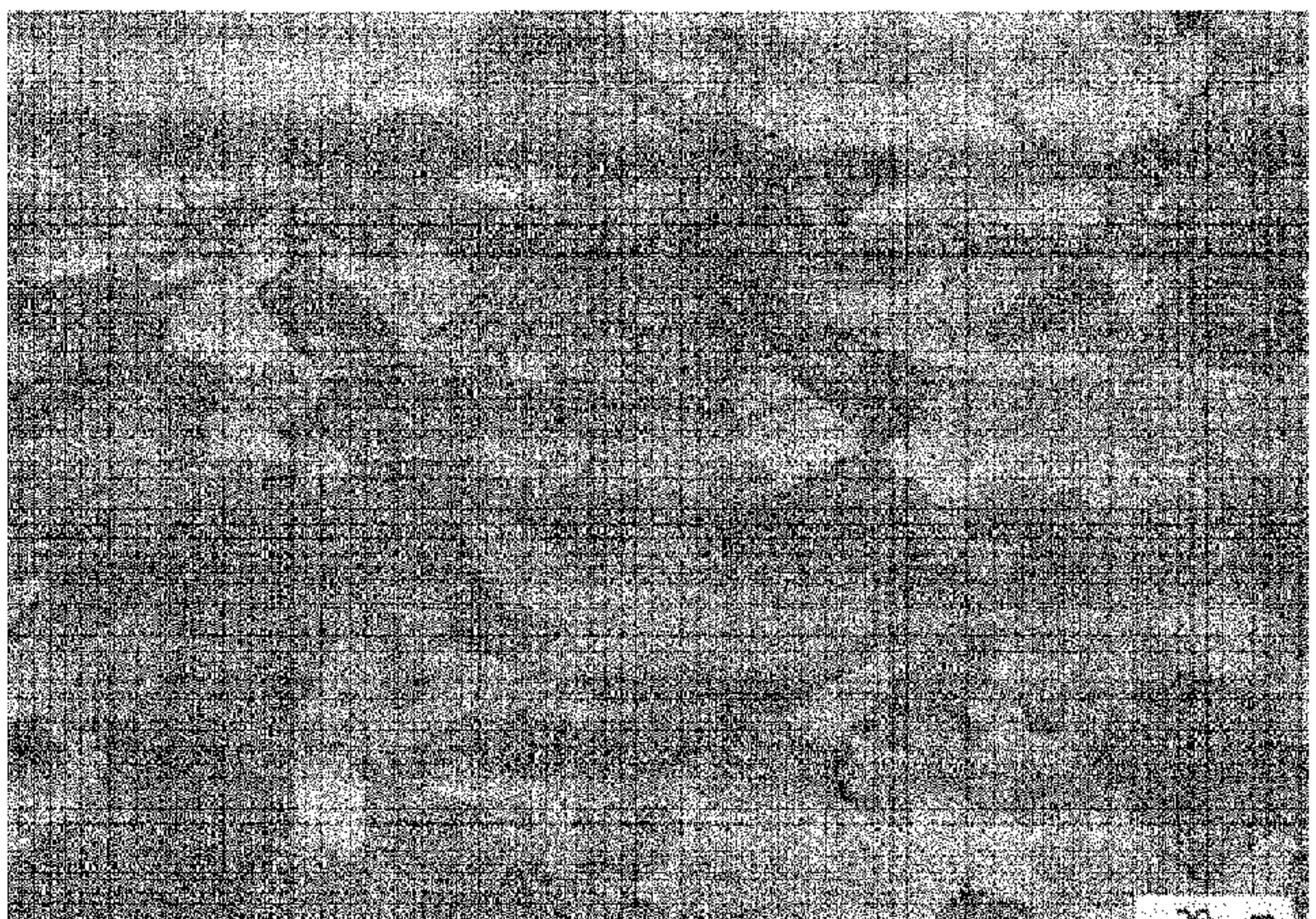
(54) Title: STEEL SHEET FOR LOW-TEMPERATURE SERVICE HAVING EXCELLENT SURFACE PROCESSING QUALITY AND METHOD FOR MANUFACTURING SAME

(54) 발명의 명칭 : 표면 가공 품질이 우수한 저온용 강판 및 그 제조방법



(57) Abstract: The present invention relates to a steel sheet for low-temperature service, which can be used at a wide temperature range from low temperature to room temperature in liquefied gas storage tanks and transport facilities, and provides: a steel sheet for low-temperature service having an excellent surface processing quality even after a processing processes is performed, such as a tension process; and a method for manufacturing the same. An aspect of the present invention relates to a steel sheet for low-temperature service having an excellent surface processing quality, the steel sheet for low-temperature service containing manganese (Mn, 15-35 wt%), carbon (C, satisfying $23.6C + Mn \geq 28$ and $33.5C - Mn \leq 23$), copper (Cu, 5 wt% or less (excluding 0 wt%)), chrome (Cr, satisfying $28.5C + 4.4Cr \leq 57$ (excluding 0 wt%)), titanium (Ti, 0.01-0.5 wt%), nitrogen (N, 0.003-0.2 wt%), the balance iron (Fe), and other inevitable impurities, wherein Ti and N satisfy relational expression 1 below. [Relational expression 1] $1.0 \leq Ti/N \leq 4.5$ (provided that, Mn, C, Cr, Ti, and N in the respective expressions mean wt% of respective ingredient contents).

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본 발명은 액화가스 저장 탱크 및 수송설비 등의 저온에서부터 실온까지 광범위한 온도에 사용할 수 있는 저온용 강판에 관한 것으로서, 인장 등의 가공 공정 후에도 표면 가공 품질이 우수한 저온용 강판 및 그 제조 방법을 제공한다. 본 발명의 일 측면은 망간(Mn): 15~35 중량%, 탄소(C): 23.6C+Mn≥28 및 33.5C-Mn≤23 을 만족하는 범위, 구리(Cu): 5 중량% 이하 (0 중량% 제외), 크롬(Cr): 28.5C+4.4Cr≤57 (0 중량% 제외)의 조건을 만족하는 범위, Ti(티타늄): 0.01~0.5 중량%, N(질소): 0.003~0.2 중량%, 나머지 철(Fe) 및 기타 불가피한 불순물을 포함하고, 상기 Ti 와 상기 N 이 하기 관계식 1 을 만족하는 표면가공 품질이 우수한 저온용 강판에 관한 것이다. [관계식 1] 1.0 ≤ Ti/N ≤ 4.5 (단, 각 수식의 Mn, C, Cr, Ti 및 N 은 각 성분함량의 중량%를 의미함)

【DESCRIPTION】

【Invention Title】

STEEL SHEET FOR LOW-TEMPERATURE SERVICE HAVING EXCELLENT SURFACE PROCESSING QUALITY AND METHOD FOR MANUFACTURING SAME

【Technical Field】

[0001] The present disclosure relates to steel for low temperature environments having excellent surface processing qualities and a method of manufacturing the same.

【Background Art】

[0002] Steel used for storage containers containing liquefied natural gas, liquid nitrogen, or the like, and used for offshore platforms and facilities in polar regions may be provided as steel for low temperature environments maintaining sufficient toughness and strength even at extremely low temperatures. Such steel for low temperature environments should have excellent low-temperature toughness, strength, and magnetic properties, as well as having relatively low coefficients of thermal expansion and thermal conductivity.

[0003] Recently, steel (Patent Document 1) having excellent extreme low temperature properties through the addition of relatively large amounts of manganese (Mn) and carbon (C), with nickel (Ni) completely excluded, to stabilize austenite and including aluminum (Al) have been used. In addition, steel (Patent Document 2) having excellent low-temperature toughness in such a manner that a mixed structure of austenite and epsilon martensite is secured by adding Mn thereto has been used.

[0004] In the case of steel for low temperature environments having austenite as a main microstructure thereof, relatively large amounts of C and Mn are added thereto, thereby stabilizing austenite. However, an addition of C and Mn affects the recrystallization behavior of austenite, thereby causing partial recrystallization and nonuniform grain growth in a rolling temperature range of the related art. Thus, only a specific small number of austenite grains are significantly grown, thereby causing significant nonuniformity in the size of austenite grains in a microstructure.

[0005] In general, in the case of austenite structures having relatively high contents of C and Mn, deformation behavior is implemented by slips and twin crystals in a manner different from general carbon steel. In addition, in the early stage of deformation, deformation behavior is usually implemented by slips corresponding to uniform deformation, but twin crystals corresponding to nonuniform deformation are subsequently accompanied thereby. When the size of grains is relatively large, stress required to form twin crystals is reduced, thereby easily generating twin crystals even in the case of a relatively low degree of deformation. In a case in which a relatively small number of coarse grains are present in a microstructure, deformation of twin crystals occurs in coarse grains in the early stage of deformation, thereby causing nonuniform deformation. Thus, surface characteristics of materials may be deteriorated, thereby causing nonuniform thicknesses of final structures. In detail, in the case of structures requiring internal pressure resistance by securing uniform thicknesses of steel, such as low-temperature pressure vessels, significant problems in structural design and use thereof occur.

[0006] Thus, in the case of steel, a microstructure of which has been austenitized by adding C and Mn thereto, steel for extreme low temperature environments, produced at low cost, which is economical and has secured structural stability by improving the uneven surfaces caused by early deformation of coarse grains into twin crystals is urgently required to be developed.

(Prior Art Document)

Patent Document 1: Korean Patent Application No. 1991-0012277

Patent Document 2: Japanese Patent Application No. 2007-126715

【Disclosure】

【Technical Problem】

[0007] An aspect of the present disclosure may provide steel for low temperature environments having excellent surface processing qualities and a method of manufacturing the same.

【Technical Solution】

[0008] According to an aspect of the present disclosure, steel for low temperature environments having excellent surface processing qualities includes 15 wt% to 35 wt% of manganese (Mn), carbon (C) satisfying 23.6C+Mn≥28 and 33.5C-Mn≤23, 5 wt% or lower of copper (Cu) (excluding 0 wt%), chrome (Cr) satisfying 28.5C+4.4Cr≤57 (excluding 0 wt%), 0.01 wt% to 0.5 wt% of titanium (Ti), 0.003 wt% to 0.2 wt% of nitrogen (N), iron (Fe) as a residual component, and inevitable impurities. Ti and N satisfy Relational Formula 1 below.

[0009] According to an aspect of the present disclosure, a method of manufacturing steel for low temperature environments having excellent surface processing qualities includes providing a slab including 15 wt% to 35 wt% of Mn, C satisfying 23.6C+Mn≥28 and 33.5C-Mn≤23, 5 wt% or lower of Cu (excluding 0 wt%), Cr satisfying 28.5C+4.4Cr≤57 (excluding 0 wt%), 0.01 wt% to 0.5 wt% of Ti, 0.003 wt% to 0.2 wt% of N, Fe as a residual component, and inevitable impurities, Ti and N satisfying Relational Formula 1 below; heating the slab at a temperature of 1050°C to 1250°C; and manufacturing heat-rolled steel by heat rolling the slab that has been heated.

[Relational Formula 1]

$1.0 \leq Ti/N \leq 4.5$,

where Mn, C, Cr, Ti, and N in each expression refer to wt% of a content of each component.

[0010] In addition, the foregoing technical solution does not list an entirety of characteristics of the present disclosure. Various characteristics of the present disclosure and consequent advantages and effects will be understood in more detail with reference to specific exemplary embodiments below.

【Advantageous Effects】

[0011] According to an aspect of the present disclosure, steel for low temperature environments having excellent surface processing qualities even after being processed due to an austenite structure having uniform particle sizes and a method of manufacturing the same may be provided.

【Description of Drawings】

[0012] FIG. 1A is an image captured using an optical microscope, illustrating a microstructure of steel for low temperature environments of the related art.

[0013] FIG. 1B is an image of a cross section of a specimen after steel for low temperature environments of the related art is tensioned.

[0014] FIG. 2 is an image captured using an optical microscope, illustrating a microstructure of steel for low temperature environments according to an exemplary embodiment in the present disclosure.

[0015] FIG. 3 is a graph illustrating ranges of carbon (C) and manganese (Mn) controlled in an exemplary embodiment.

【Best Mode for Invention】

[0016] The inventors recognized that, in the case of steel having an austenite structure, containing a relatively large amount of carbon (C) and manganese (Mn), partial recrystallization and grain growth of the austenite structure occurs in a rolling temperature range of the related art, thereby generating abnormally coarse austenite; in general, critical stress required to form a twin crystal is higher than that of a slip, but in a case in which a size of a grain is relatively great for the reason described above, stress required to form the twin crystal is reduced, thereby causing deformation of the twin crystal in the early state of deformation, so that a problem in which surface quality may be degraded due to discontinuous deformation may occur. In addition, the inventors have conducted in-depth research to solve the problem described above.

[0017] Thus, the inventors confirmed that steel for low temperature environments in which fine austenite is uniformly distributed may be obtained in such a manner that a titanium

(Ti)-based precipitate is properly educed by adding Ti thereto, in order to suppress significant coarsening of an austenite grain and realized the present disclosure.

[0018] Hereinafter, steel for low temperature environments having excellent surface processing qualities according to an exemplary embodiment will be described in detail.

[0019] According to an aspect of the present disclosure, the steel for low temperature environments having excellent surface processing qualities includes 15 wt% to 35 wt% of manganese (Mn), carbon (C) satisfying $23.6C+Mn \geq 28$ and $33.5C-Mn \leq 23$, 5 wt% or lower of copper (Cu) (excluding 0 wt%), chrome (Cr) satisfying $28.5C+4.4Cr \leq 57$ (excluding 0 wt%), 0.01 wt% to 0.5 wt% of titanium (Ti), 0.003 wt% to 0.2 wt% of nitrogen (N), iron (Fe) as a residual component, and inevitable impurities. In addition, Ti and N satisfy Relational Formula 1 below.

[Relational Formula 1]

$$1.0 \leq Ti/N \leq 4.5,$$

where Mn, C, Cr, Ti, and N in each expression refer to wt% of a content of each component.

[0020] First, an alloy composition of the steel for low temperature environments having excellent surface processing qualities according to an exemplary embodiment will be described in detail. Hereinafter, a unit of each alloying element is wt%.

Manganese (Mn): 15% to 35%

[0021] Mn is an element playing a role in stabilizing austenite in an exemplary embodiment. 15% or more of Mn may be contained to stabilize an austenite phase at extremely low temperatures. In other words, in a case in which an Mn content is lower than 15%, when a C content is relatively low, metastable phase epsilon martensite is formed and easily transformed into α-martensite by strain induced transformation at extremely low temperatures, thereby not securing toughness. In a case in which the C content is increased to stabilize austenite to prevent the case described above, physical properties thereof may be dramatically degraded due to carbide precipitation. Thus, the Mn content may be higher than or equal to 15%. On the other hand, in a case in which the Mn content is higher than 35%, a problem in which a corrosion rate of steel is increased, and economic feasibility is reduced due to an increase in the Mn content occurs. Thus, the Mn content may be limited to a range of 15% to 35%.

Carbon (C): 23.6C+Mn≥28 and 33.5C-Mn≤23

[0022] C is an element stabilizing austenite and increasing strength. In detail, C plays a role in reducing M_S and M_d, transformation points in which austenite is transformed into epsilon martensite or α-martensite by a cooling process or a process. Thus, in a case in which C is insufficiently added, stability of austenite is insufficient, thereby not obtaining stable austenite at extremely low temperatures. In addition, external stress causes strain induced transformation in which austenite is easily transformed into epsilon martensite or α-martensite, and toughness and the strength of steel is reduced. On the other hand, in a case in which the C content is significantly high, toughness is dramatically degraded due to carbide precipitation, and workability is degraded due to a significant increase in strength.

[0023] In detail, the C content in an exemplary embodiment may be decided in consideration of a relationship between C and other elements added thereto. To this end, a relationship between C and Mn in forming a carbide that the inventor has discovered is illustrated in FIG. 3. As illustrated in FIG. 3, the carbide is formed using C. C does not independently affect formation of the carbide, but affects a tendency to form the carbide in combination with Mn.

[0024] FIG. 3 illustrates a proper C content. In order to prevent the carbide from being generated, on a premise that other components satisfy a range made in an exemplary embodiment, a value of 23.6C+Mn (in the case of C and Mn, a content of each component is expressed using wt%) may be controlled to be higher than or equal to 28. The value refers to a leftward diagonal line in a hexagonal area in FIG. 3. In a case in which 23.6C+Mn is lower than 28, stability of austenite is decreased, and strain induced transformation is generated by impacts at extremely low temperatures, thereby degrading impact toughness. In a case in which the C content is significantly high, that is, 33.5C-Mn is higher than 23, an addition of a significant amount of C causes carbide precipitation, thereby degrading low-temperature impact toughness. In conclusion, C may be added to satisfy an entirety of Mn: 15% to 35%, 23.6C+Mn≥28, and 33.5C-Mn≤23. As illustrated in FIG. 3, a lowermost limit of the C content is 0%, within a range satisfying the expression above.

Copper (Cu): 5% or lower (excluding 0%)

[0025] Cu has significantly low solid solubility in the carbide and is relatively slow in spreading in austenite, thereby being concentrated in austenite and at an interface of a nucleated carbide. Thus, spreading of C is interrupted, thereby effectively slowing carbide growth. As a result, a generation of the carbide is suppressed. In addition, Cu stabilizes austenite to improve extreme low-temperature toughness. However, in a case in which a Cu content is higher than 5%, hot workability of steel is degraded. Thus, an uppermost limit may be limited to 5%. In addition, the Cu content to obtain an effect of suppressing the carbide as described above may be higher than or equal to 0.5%.

Chrome (Cr): 28.5C+4.4Cr ≤ 57 (excluding 0%)

[0026] Cr plays a role in improving impact toughness at low temperatures by stabilizing austenite and increasing the strength of steel through being solubilized in austenite within a range of a proper content thereof. In addition, Cr is an element improving corrosion resistance of steel. However, Cr is a carbide element. In detail, Cr is also an element forming the carbide in an austenite grain boundary to reduce the impact of low-temperatures. Thus, a Cr content in an exemplary embodiment may be determined in consideration of the relationship between C and other elements added thereto. In order to prevent the carbide from being generated, on a premise that other components satisfy a range made in an exemplary embodiment, a value of 28.5C+4.4Cr (in the case of C and Cr, a content of each component is expressed using wt%) may be controlled to be lower than or equal to 57. In a case in which the value of 28.5C+4.4Cr is higher than 57, the generation of the carbide in the austenite grain boundary is difficult to suppress effectively, due to significant contents of Cr and C, thereby causing a problem in which impact toughness at low temperatures is degraded. Thus, Cr may be added to satisfy 28.5C+4.4Cr ≤ 57 in an exemplary embodiment.

Titanium (Ti): 0.01% to 0.5%

[0027] Ti is an element forming a TiN precipitate in combination with nitrogen (N). In an exemplary embodiment, during high-temperature hot rolling, a portion of the austenite grain may be significantly coarse. Thus, growth of the austenite grain may be suppressed by properly educing TiN. To this end, at least 0.01% or more of Ti is required to be added. However, in a case in which a Ti content is higher than 0.5%, an effect of growth of the austenite grain may not be improved anymore. In addition, coarse TiN is educed, thereby reducing an effect of growth of the austenite grain. Thus, in an exemplary embodiment, the Ti content may be limited to a range of 0.01% to 0.5%.

Nitrogen (N): 0.003% to 0.2 wt%

[0028] In an exemplary embodiment, in order to effectively achieve a goal of adding Ti described above, N is required to be added simultaneously. In detail, in order to effectively educe TiN, 0.003% or more of N may be added. However, since solid solubility of N is lower than or equal to 0.2%, an addition of 0.2% or greater of N is significantly difficult, and 0.2% or less thereof is sufficient to educe TiN, thereby limiting an uppermost limit thereof to 0.2%. Thus, an N content may be limited to a range of 0.003% to 0.2% in an exemplary embodiment.

[0029] A residual component of an exemplary embodiment is Fe. However, since, in a manufacturing process of the related art, unintentional impurities may be inevitably mixed from a raw material or a surrounding environment, unintentional impurities are unavoidable. Since the impurities are known to those skilled in the manufacturing process of the related art, descriptions thereof will not be provided in detail in an exemplary embodiment.

[0030] In addition, a weight ratio of Ti to N, that is, Ti/N, may satisfy Relational Formula 1 below.

[Relational Formula 1]

$$1.0 \leq Ti/N \leq 4.5$$

[0031] In a case in which a Ti/N ratio is controlled to be higher than or equal to 1.0, solute Ti is combined with N, thereby educing minute TiN. In addition, since TiN that has been educed using a method described above is stably present, the growth of the austenite grain may be effectively suppressed.

[0032] However, in a case in which the Ti/N ratio is higher than 4.5, coarse TiN is crystallized in molten steel, thereby adversely affecting a property of steel and not obtaining uniform distribution of TiN. In addition, surplus Ti that has not been educed to be TiN is present in a state of solid solution, thereby adversely affecting heat-affected zone toughness. However, in a case in which the Ti/N ratio is lower than 1.0, an amount of solute N in a base metal is increased, thereby adversely affecting heat-affected zone toughness. Thus, the

Ti/N ratio may be controlled to be 1.0 to 4.5.

[0033] In addition, the steel for low temperature environments according to an exemplary embodiment described above may include the TiN precipitate having a size of 0.01μm to 0.3μm.

[0034] In a case in which a size of the TiN precipitate is less than 0.01 μm, the TiN precipitate is easily solubilized, so that an effect of suppressing grain growth becomes insufficient. On the other hand, in a case in which the size of the TiN precipitate is greater than 0.3 μm, an austenite grain pinning effect is reduced, and a coarse size thereof adversely affects toughness. Thus, the size of the TiN precipitate may be within a range of 0.01 μm to 0.3 μm.

[0035] In addition, the steel for low temperature environments according to an exemplary embodiment may include the TiN precipitate in an amount of 1.0×10^{7} to 1.0×10^{10} per 1 mm^2.

[0036] In a case in which the TiN precipitate is present in an amount less than 1.0×10^{7} per 1 mm^2, a grain pinning effect is insignificant, thereby not effectively suppressing growth of a coarse grain. On the other hand, in a case in which the TiN precipitate is present in an amount greater than 1.0×10^{7} per 1 mm^2, the size of the TiN precipitate becomes relatively small, so that the TiN precipitate may be unstable, and impact toughness of a material thereof may be degraded. Thus, the amount of the TiN precipitate may be 1.0×10^{7} to 1.0×10^{10} per 1 mm^2.

[0037] In addition, the steel for low temperature environments according to an exemplary embodiment limits the number of coarse austenite grains having a size of 200 μm or greater in the microstructure to 5 or less per 1 cm^2.

[0038] Since, in the case of austenite having a grain size less than 200 μm, stress required to generate the twin crystal is sufficiently higher than stress required to generate a slip, nonuniform transformation is not generated within a transformation rate of steel for low temperature environments of the related art when a structure is manufactured. Thus, the size thereof may be limited to 200 μm or greater. In addition, in a case in which the density of a grain having a size of 200 μm or greater is greater than 5 per 1 cm^2, due to a relatively high density of the coarse grain, nonuniform transformation is sufficiently deteriorated to affect surface qualities. Thus, the density of the grain having a size of 200 μm or greater may be limited to 5 or less per 1 cm^2.

[0039] In the meantime, the steel for low temperature environments according to an exemplary embodiment may include an austenite structure in an area fraction of 95% or higher. Austenite, a representative soft structure in which ductile fracture is generated even at low temperatures, is an essential microstructure to secure low-temperature toughness and should be included in an area fraction of 95% or higher. In a case in which austenite is included in an area fraction of lower than

95%, austenite is not sufficient to secure low-temperature toughness, that is, impact toughness of 41 J or greater at a temperature of -196°C, so that a lowermost limit thereof may be limited to 95%.

[0040] In addition, the carbide present in the austenite grain boundary may be lower than or equal to 5% in an area fraction. In an exemplary embodiment, the carbide is a representative structure that may be present, beside austenite. The carbide is educed in an austenite grain boundary and becomes a cause of grain boundary rupture, thereby degrading low-temperature toughness and ductility. Thus, an uppermost limit thereof may be limited to 5%.

[0041] Hereinafter, a method of manufacturing the steel for low temperature environments having excellent surface processing qualities according to another exemplary embodiment will be described in detail.

[0042] The method of manufacturing the steel for low temperature environments having excellent surface processing qualities according to another exemplary embodiment includes providing a slab satisfying the alloy composition described above, heating the slab at a temperature of 1050°C to 1250°C, and manufacturing hot-rolled steel by hot rolling the slab that has been heated.

Providing a slab

[0043] The slab satisfying the alloy composition described above is provided. A reason for controlling the alloy composition is the same as described above.

Heating a slab

[0044] The slab is heated at the temperature of 1050°C to 1250°C.

[0045] A process described above is performed for the sake of solution and homogenization of a cast structure, segregation, and secondary phases generated in a process of manufacturing the slab. In a case in which the temperature is lower than 1050°C, homogenization thereof is insufficient or a temperature of a heating furnace is significantly low, thereby causing a problem in which deformation resistance is increased during heat rolling. In a case in which the temperature is higher than 1250°C, partial melting may occur and surface qualities may be degraded in segregation in the cast structure, and TiN may be crystallized, thereby not contributing to austenite refinement, but degrading properties thereof. Thus, a heating temperature of the slab may be in a range of 1050°C to 1250°C.

Manufacturing hot-rolled steel

[0046] The slab that has been heated is heat rolled, thereby manufacturing the hot-rolled steel.

[0047] In an exemplary embodiment, the alloy composition and the heating temperature of the slab, described above, may be satisfied, thereby manufacturing the steel for low temperature environments having excellent surface processing qualities. Thus, in detail, it is not necessary to control a condition of the manufacturing hot-rolled steel and the manufacturing hot-rolled steel may be performed using a general method.

【Industrial Applicability】

[0048] Hereinafter, the present disclosure will be described in more detail through exemplary embodiments. However, an exemplary embodiment below is intended to describe the present disclosure in more detail through illustration thereof, but not limit the scope of rights of the present disclosure, because the scope of rights thereof is determined by the contents written in the appended claims and can be reasonably inferred therefrom.

[0049] After a slab satisfying a component system stated in Table 1 below is manufactured in the same manner as a manufacturing condition stated in Table 2, a microstructure, yield strength, an elongation rate, Charpy impact toughness at a temperature of -196°C, or the like, are measured to be stated in Table 2 or Table 3, respectively.

[0050] In Table 3 below, unevenness of surfaces is assessed by observing surfaces of the steel for low temperature environments with the naked eye.

【Table 1】

Classification	C	Mn	Cu	Cr	N	Ti	Weight Ratio of Ti/N	23.6C+Mn	33.5C-Mn	28.5C+4.4Cr
Comparative Example 1	0.62	18.12	0.12	0.2	0.012			32.8	2.7	18.6
Comparative Example 2	0.37	25.4	1.12	3.85	0.018			34.1	-13.0	27.5
Comparative Example 3	0.61	18.13	1.5	1.25	0.012			32.5	2.3	22.9
Comparative Example 4	0.31	28.7	0.15	1.32	0.025	0.024	0.96	36.0	-18.3	14.6
Comparative	0.45	11.7			0.008	0.07	8.75	22.3	3.4	12.8

Example 5										
Comparative Example 6	0.37	24.1	1.02	3.5	0.011	0.05	4.55	32.8	-11.7	25.9
Inventive Example 1	0.58	21.7	0.61	0.55	0.053	0.06	1.13	35.388	-2.3	19.0
Inventive Example 2	0.45	24.3	0.43	3.08	0.12	0.17	1.42	34.92	-9.2	26.4
Inventive Example 3	0.39	28.6	0.85	3.45	0.016	0.02	1.25	37.804	-15.5	26.3
Inventive Example 4	0.44	27.5	0.42	1.62	0.024	0.04	1.67	37.884	-12.8	19.7
Inventive Exampl	1.1	23.4	1.05	0.87	0.021	0.05	2.38	49.36	13.5	35.2

e 5										

[0051] In Table 1 above, a unit of a content of each element is wt%.

【Table 2】

Classification	Temperature of Heating Furnace (°C)	Austenite Fraction (%)	Carbide Fraction (%)	TiN Size (μm)	No. of TiN (No./mm²)	Density of Coarse Grain of 200 μm or greater (No./cm²)
Comparative Example 1	1195	99.1	0.9			10
Comparative Example 2	1180	99.6	0.4			7
Comparative Example 3	1200	99	1			8

Comparative Example 4	1195	98.9	0.8	0.003	$1.2X10^{4}$	7
Comparative Example 5	1200	82	1	1.25	$4.32X10^{5}$	7
Comparative Example 6	1195	99.6	0	0.95	$5.2X10^{6}$	9
Inventive Example 1	1205	99.1	0.8	0.013	$5.3X10^{8}$	0
Inventive Example 2	1190	99.3	0	0.015	$4.2X10^{8}$	0
Inventive Example 3	1195	99.4	0	0.022	$2.9X10^{8}$	1
Invent	1198	99.6	0	0.012	$5.4X10^{8}$	0

ive Exampl e 4						
Invent ive Exampl e 5	1203	98.7	0.8	0.025	2.7X10^{8}	0

【Table 3】

Classi ficati on	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation Rate (%)	Base Metal Impact Value (J, -196℃)	Unevenness of Surfaces
Compar ative Exampl e 1	363	1011	69	83	Occurred
Compar ative Exampl e 2	470	931	46	130	Occurred
Compar ative Exampl e 3	405	1006	57	81	Occurred
Compar	411	912	57	130	Occurred

ative Example 4					
Comparative Example 5	346	762	12	38	Occurred
Comparative Example 6	360	926	54	35	Occurred
Inventive Example 1	425	980	67	153	Not Occurred
Inventive Example 2	453	902	58	148	Not Occurred
Inventive Example 3	468	975	61	165	Not Occurred
Inventive	427	980	65	152	Not Occurred

Example 4					
Inventive Example 5	481	971	51	118	Not Occurred

[0052] In Inventive Examples 1 to 5, it can be confirmed that a component system and a composition range controlled in an exemplary embodiment are satisfied, and high-quality steel for low temperature environments without uneven surfaces may be obtained in such a manner that a density of a coarse austenite grain is controlled to be 5 or less per 1 cm^2 by minute eduction of TiN, and Inventive Examples 1 to 5 are processed. In addition, stable austenite in which fraction of austenite in the microstructure is controlled to be 95% or higher, and fraction of the carbide is controlled to be lower than 5% may be obtained, thereby securing excellent toughness at extremely low temperatures.

[0053] On the other hand, in Comparative Examples 1 to 3, it can be confirmed that TiN may not be educed, since Ti is not added thereto, thereby generating a coarse grain and unevenness of surfaces after Comparative Examples 1 to 3 are processed.

[0054] In detail, in the case of Comparative Example 4, it can be confirmed that, since the component system and the composition range controlled in an exemplary embodiment are not satisfied, ferrite is generated, thereby significantly degrading impact toughness. In addition, it can be confirmed that, since a size and the number of TiN controlled in an exemplary embodiment are not satisfied, the number of coarse grains is increased, thereby generating unevenness of surfaces.

[0055] In addition, in the case of Comparative Examples 5 to 6, it can be confirmed that Ti and N within a range controlled in an exemplary embodiment are added, but the weight ratio of Ti to N and a size and the number of the TiN precipitate do not satisfy the range controlled in an exemplary embodiment, so that coarse TiN is educed, and the coarse grain is significantly generated to generate unevenness of surfaces after Comparative Examples 5 to 6 are processed.

[0056] FIG. 1A is an image of the microstructure of steel of the related art in which a nonideal coarse grain is formed by coarsening of the austenite grain. FIG. 1B is an image of unevenness occurring on a surface of steel after steel of FIG. 1A is tensioned. As such, it can be confirmed that, in a case in which the austenite grain is coarsened to generate the nonideal coarse grain in the microstructure of steel, surface qualities are degraded after a process thereof as described in FIG. 1B. However, in FIG. 2, illustrating an image of the microstructure of Inventive Examples, uniform grains without a nonideal coarse austenite grain is formed, thereby generating excellent surface processing qualities even after the process thereof.

[0057] While exemplary embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present invention as defined by the appended claims.

【CLAIMS】

【Claim 1】

Steel for low temperature environments having excellent surface processing qualities, comprising:

15 wt% to 35 wt% of manganese (Mn), carbon (C) satisfying $23.6C+Mn \geq 28$ and $33.5C-Mn \leq 23$, 5 wt% or lower of copper (Cu) (excluding 0 wt%), chrome (Cr) satisfying $28.5C+4.4Cr \leq 57$ (excluding 0 wt%), 0.01 wt% to 0.5 wt% of titanium (Ti), 0.003 wt% to 0.2 wt% of nitrogen (N), iron (Fe) as a residual component, and inevitable impurities,

wherein Ti and N satisfy Relational Formula 1 below.

[Relational Formula 1]

$1.0 \leq Ti/N \leq 4.5$,

where Mn, C, Cr, Ti, and N in each expression refer to wt% of a content of each component.

【Claim 2】

The steel for low temperature environments having excellent surface processing qualities of claim 1, wherein the steel comprises a TiN precipitate having a size of 0.01 μm to 0.3 μm.

【Claim 3】

The steel for low temperature environments having excellent surface processing qualities of claim 1, wherein the steel comprises a TiN precipitate in an amount of 1.0×10^7 to

1.0×10^{10} per $1 mm^2$.

【Claim 4】

The steel for low temperature environments having excellent surface processing qualities of claim 1, wherein a number of austenite grains having a size of 200 μm or greater is 5 or less per $1 cm^2$ in a microstructure of the steel.

【Claim 5】

The steel for low temperature environments having excellent surface processing qualities of claim 1, wherein a microstructure of the steel comprises austenite in an area fraction of 95% or greater.

【Claim 6】

The steel for low temperature environments having excellent surface processing qualities of claim 5, wherein a carbide present in a grain boundary of austenite is lower than or equal to 5% in an area fraction.

【Claim 7】

The steel for low temperature environments having excellent surface processing qualities of claim 1, wherein impact toughness of the steel is higher than or equal to 41 J at a temperature of -196°C.

【Claim 8】

A method of manufacturing steel for low temperature environments having excellent surface processing qualities, comprising:

providing a slab including 15 wt% to 35 wt% of Mn, C satisfying 23.6C+Mn≥28 and 33.5C-Mn≤23, 5 wt% or lower of Cu (excluding 0 wt%), Cr satisfying 28.5C+4.4Cr≤57 (excluding 0 wt%), 0.01 wt% to 0.5 wt% of Ti, 0.003 wt% to 0.2 wt% of N, Fe as a residual component, and inevitable impurities, Ti and N satisfying Relational Formula 1 below;

heating the slab at a temperature of 1050°C to 1250°C; and

manufacturing heat-rolled steel by heat rolling the slab that has been heated.

[Relational Formula 1]

$1.0 \leq Ti/N \leq 4.5$,

where Mn, C, Cr, Ti, and N in each expression refer to wt% of a content of each component.

【Claim 9】

The method of claim 8, wherein the steel comprises a TiN precipitate having a size of 0.01 μm to 0.3 μm.

【Claim 10】

The method of claim 8, wherein the steel comprises a TiN precipitate in an amount of 1.0×10^{7} to 1.0×10^{10} per 1 mm^2.

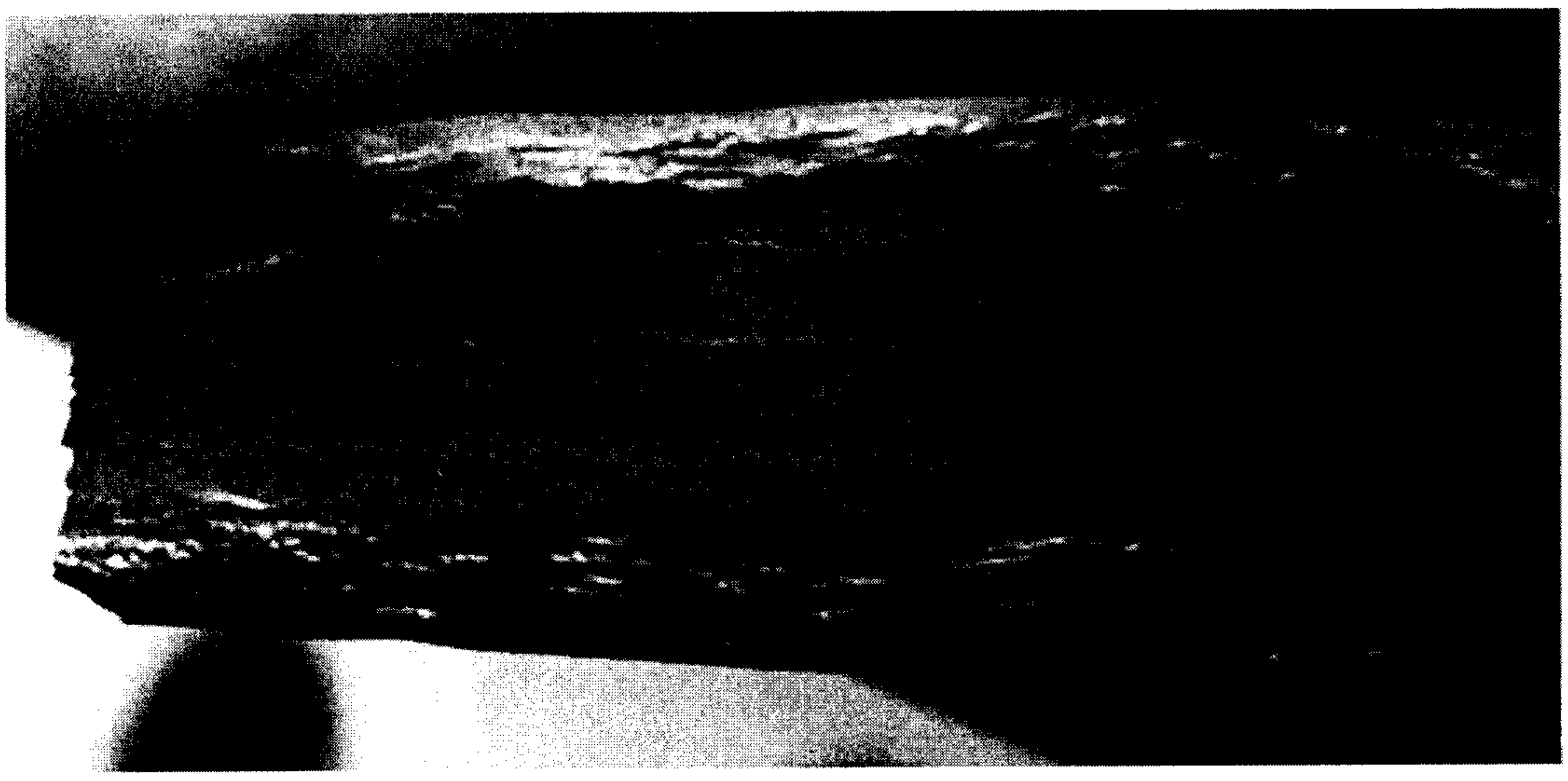
【Claim 11】

The method of claim 8, wherein a number of austenite grains having a size of 200 μm or greater is 5 or less per 1 cm^2 in a microstructure of the steel.

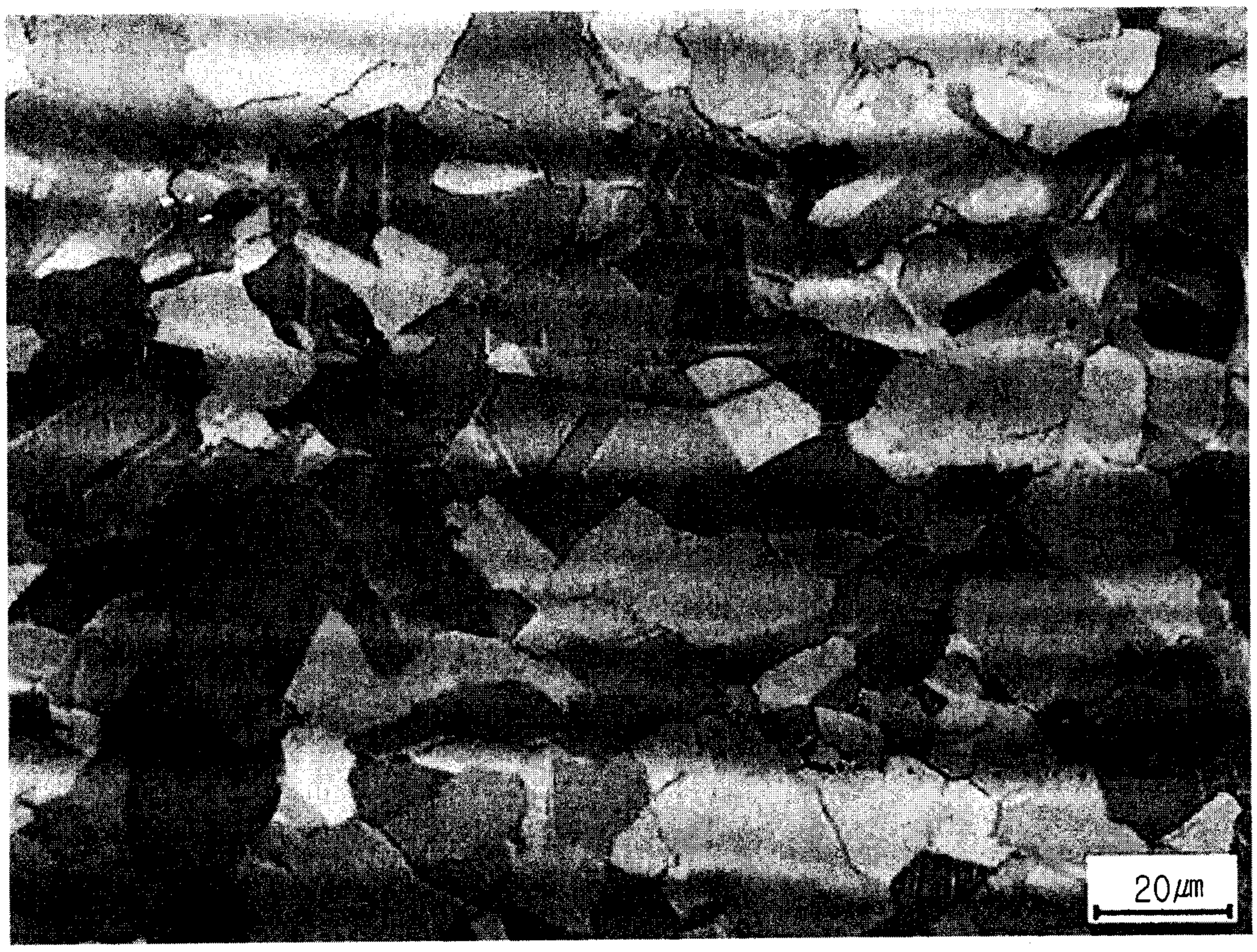
【DRAWINGS】

【FIG. 1A】

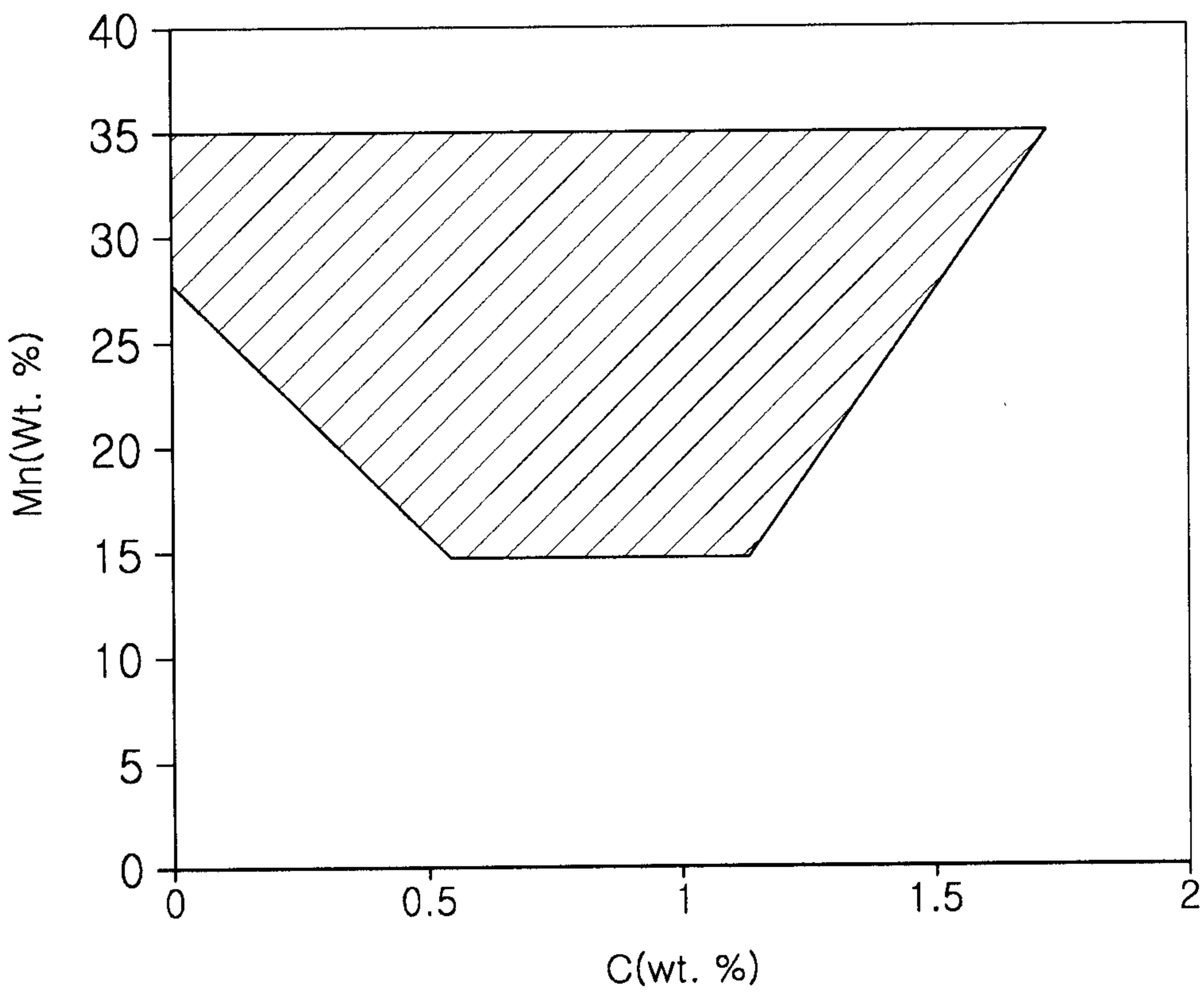
【FIG. 1B】



【FIG. 2】



【FIG. 3】



【FIG. 1A】