(54) **STEEL MATERIAL FOR SEISMIC DAMPER HAVING SUPERIOR IMPACT TOUGHNESS, AND MANUFACTURING METHOD FOR SAME**

(57)   The present invention provides a steel material for a seismic damper, and a manufacturing method for same. The steel material comprises, in wt%, at most 0.006% of C, at most 0.05% of Si, at most 0.3% of Mn, at most 0.02% of P, at most 0.01% of S, 0.005 to 0.05% of Al, at most 0.005% of N, 48/14X[N] to 0.05% of Ti (here,[N] is the nitrogen content in wt%), 0.04 to 0.15% of Nb, and the remainder in Fe and other unavoidable impurities, and has a ferrite single structure, and has a ferrite grain average particle size of 150 to 500 um in a region of a surface layer part, corresponding to 30% of the total thickness from the surface thereof.

FIG. 1A

UPPER SURFACE LAYER COARSE GRAIN PART (3mm)

OPTICAL IMAGE IN A REGION

UPPER SURFACE LAYER COARSE GRAIN PART (5mm)

OPTICAL IMAGE IN B REGION

OPTICAL IMAGE IN BORDER REGION
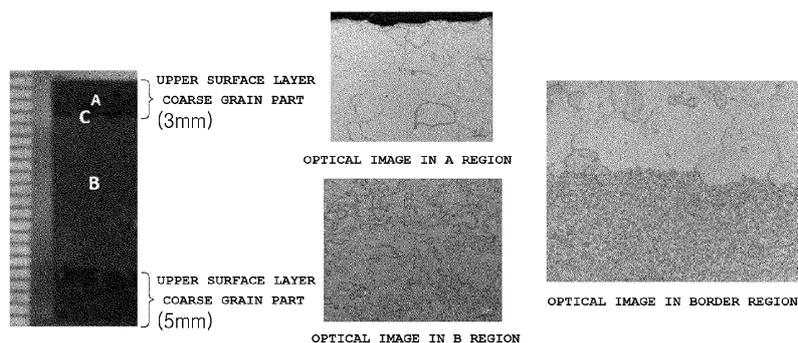
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Description

Technical Field

[0001]   The present invention relates to a steel material for a seismic damper used to secure seismic resistance of a structure against an earthquake and a manufacturing method for the same.

Background Art

[0002]   In seismic design, which has been mainly used in Korea in the past, a technology of lowering a yield ratio of a steel material used in a structure of a column or beam during an earthquake to delay a point in time at which destruction of the structure occurs, was mainly used. However, the seismic design using such a steel material having a low yield ratio had a problem in that it is impossible to reuse the steel material used in the structure, and the structure itself should be reconstructed due to the absence of securing stability.

[0003]   Recently, with the development of seismic design technology, a practical use of a seismic damping or vibration damping structure is progressing. In particular, various technologies for securing seismic performance by absorbing energy applied to a structure by an earthquake to a specific portion thereof are being developed. A seismic damper is used as a device for absorbing such seismic energy, and a steel material for the seismic damper has an ultra-low yield point characteristic. By lowering a yield point of the steel material for the seismic damper further than the existing structural material of a column or a beam, the steel material first yields during an earthquake to absorb vibration energy caused by the earthquake, and suppresses deformation of the structure by maintaining other structural materials within a range of elasticity.

[0004]   (Patent Document 1) Patent Publication No. 2008-0088605

Summary of Invention

Technical Problem

[0005]   An aspect of the present disclosure is to provide a steel material for a seismic damper, which has low yield strength and can be used to secure seismic resistance of a structure against an earthquake, and a manufacturing method for the same.

[0006]   Alternatively, another aspect of the present disclosure is to provide a steel material for a seismic damper having low yield strength and excellent low-temperature impact toughness simultaneously, and a manufacturing method for the same.

[0007]   An object of the present disclosure is not limited to the above description. The object of the present disclosure will be understood from the entire content of the present specification, and a person skilled in the art to which the present disclosure pertains will understand an additional object of the present disclosure without difficulty.

Solution to Problem

[0008]   According to an aspect of the present disclosure,

provided is a steel material for a seismic damper, the steel material including, by weight: 0.006% or less of C, 0.05% or less of Si, 0.3% or less of Mn, 0.02% or less of P, 0.01% or less of S, 0.005 to 0.05% of Al, 0.005% or less of N, $48/14 \times [N]$ to 0.05% of Ti, where, [N] refers to a content of nitrogen (weight %), , and 0.04 to 0.15% of Nb, with a balance of Fe and other unavoidable impurities,
having a ferrite single structure,
wherein an average ferrite grain size in a surface layer portion, from a surface thereof to a region corresponding to 30% of a total thickness is 150 to 500 μm.

[0009]   According to another aspect of the present disclosure,

provided is a manufacturing method for a steel material for a seismic damper, the method including: heating a steel slab including by weight: 0.006% or less of C, 0.05% or less of Si, 0.3% or less of Mn, 0.02% or less of P, 0.01% or less of S, 0.005 to 0.05% of Al, 0.005% or less of N, $48/14 \times [N]$ to 0.05% of Ti, where, [N] refers to a content of nitrogen (weight %), and 0.04 to 0.15% of Nb, with a balance of Fe and other unavoidable impurities, to a temperature within a range of 1050 to 1250°C;
subjecting the heated steel slab to finish rolling in a temperature range of Ar3-80°C or higher and Ar3 or lower; and

performing a shot blasting treatment operation on a surface of the finish-rolled steel material,
wherein the shot blasting treatment operation is performed so that a metallic ball or a non-metallic ball is rotated at a rate of 1500 to 2500 rpm and sprayed on a surface of the plate material at a rate of 60 to 100 m/s.

Advantageous Effects of Invention

[0010]   As set forth above, according to an aspect of the present disclosure, a steel material that can be suitably used for a seismic damper used to secure seismic resistance of a structure against an earthquake and a manufacturing method for the same may be provided.

[0011]   Alternatively, according to another aspect of the present disclosure, a steel material for a seismic damper having low yield strength and excellent low-temperature impact toughness and a manufacturing method for the same may be provided.

[0012]   Various and beneficial merits and effects of the present disclosure are not limited to the descriptions above, and may be more easily understood in a process of describing specific exemplary embodiments in the present disclosure.

Brief description of drawings

[0013]

FIG. 1 illustrates a photograph of a microstructure in a surface layer portion and an inner region other than the surface layer portion, of a steel material of the present disclosure, captured with an optical microscope. In addition, FIG. 1B illustrates an enlarged view of region A in FIG. 1A, FIG. 1C illustrates an enlarged view of region B in FIG. 1A, and FIG. 1D illustrates an enlarged view of region C in FIG. 1A.

FIG. 2 is a graph illustrating a change in a recrystallization stop temperature (Tnr) according to an amount of Nb added to the steel of the present disclosure.

FIG. 3 is a graph illustrating a change in yield strength according to an average grain size in a surface layer portion and an average grain size in an inner region other than the surface layer portion, of a steel material of the present disclosure.

FIG. 4 is a graph illustrating a change in a thickness ratio of upper and lower surface layer portions with respect to the total thickness of the steel material according to an LMP, a parameter represented by a heat treatment temperature and time.

FIG. 5 is a graph illustrating a change in yield strength according to the thickness ratio of the upper and lower surface layer portions with respect to the thickness of the steel material.

Best Mode for Invention

[0014]   Hereinafter, preferred embodiments of the present disclosure will be described. However, embodiments of the present disclosure may be modified in various forms, and the scope of the present disclosure should not be construed as being limited to the embodiments described below. The present embodiments are provided to those skilled in the art to further elaborate the present disclosure.

[0015]   As a steel material used to secure seismic resistance of a structure against an earthquake, conventionally, a technology of using a component close to pure iron and performing an additional heat treatment in a range of 910 to 960°C, has been known.

[0016]   However, since this technology requires an additional heat treatment at a high temperature of 900°C or higher after finish rolling, an excessive scale occurs in the case of a steel material having an ultra-low yield point to which Si is not added, so that defects occur, or coarse Nb or Ti precipitates are formed, so that there was a problem in that deterioration in impact toughness occurs. In addition, since an additional heat treatment process at a high temperature of 900°C or higher is included, there was also a problem of causing an increase in manufacturing costs.

[0017]   Accordingly, in order to solve the problems described above, as a result of the examples thereof, by optimizing a composition of steel, and a microstructure and manufacturing conditions of a surface layer portion, the present inventors have developed that it is possible to provide a steel material having a yield strength as low as 120 MPa or less and excellent low-impact toughness, and thus the present disclosure was provided.

[0018]   Hereinafter, [a steel material for a seismic damper] according to the present disclosure will be described in detail.

[0019]   Specifically, the steel material for a seismic damper has a composition including by weight: 0.006% or less of C, 0.05% or less of Si, 0.3% or less of Mn, 0.02% or less of P, 0.01% or less of S, 0.005 to 0.05% of Al, 0.005% or less of N, $48/14 \times [N]$ to 0.05% of Ti, with a balance of Fe and other unavoidable impurities. Hereinafter, a reason for adding each alloy component constituting the composition of steel, which is one of the main characteristics of the present disclosure, and an appropriate content range thereof will first be described.

C: 0.006% or less (excluding 0%)

[0020] C is an element causing solid solution strengthening and is fixed to dislocations in a free state to increase yield strength and decrease elongation. In order to secure the effects described above, in the present disclosure, a case in which a C content is 0% is excluded (i.e., the C content exceeds 0%). Therefore, in order to be suitably used as a steel material for a seismic damper, the lower the C content, the better, so the C content is controlled to be 0.006% or less, and more preferably is controlled to be 0.0045% or less. In addition, more preferably, the C content may be 0.0005% or more.

Si: 0.05% or less (excluding 0%)

[0021] Si, like C, is an element causing solid solution strengthening, to increase yield strength and lower elongation. In order to secure the effects described above, a case in which an Si content is 0% is excluded (i.e., the Si content exceeds 0%). However, in order to be suitably used as a steel material for a seismic damper, the lower the Si content, the better. Therefore, in the present disclosure, the Si content can be controlled to be 0.03% or less, more preferably be controlled to be 0.013% or less, in terms of securing low yield strength. In addition, the Si content may be 0.001% or more.

Mn: 0.3% or less (excluding 0%)

[0022] Mn, like Si, is an element causing solid solution strengthening, to increase yield strength and lower elongation. In order to secure the effects described above, a case in which a Mn content is 0% is excluded (i.e., the Mn content exceeds 0%). However, in order to be suitably used as a steel material for a seismic damper, in the present disclosure, the Mn content may be controlled to be 0.3% or less, more preferably may be controlled to be 0.2% or less, in terms of securing low yield strength. In addition, the Mn content may be 0.06% or more, and more preferably may be 0.1% or more.

P: 0.02% or less (excluding 0%)

[0023] Since P is an element that is advantageous for strength improvement and corrosion resistance, a case in which a P content is 0% is excluded (i.e., the P content exceeds 0%) in order to secure the effects described above. Since P may greatly impair impact toughness, it is preferable to maintain the P content to be as low as possible. Therefore, in the present disclosure, the P content may be controlled to be 0.02% or less, more preferably 0.013% or less. In addition, the P content may be 0.001% or more, and more preferably 0.004% or more.

S: 0.01% or less (excluding 0%)

[0024] Since S is an element that forms MnS, and the like to greatly impair impact toughness, it is preferable to keep an S content as low as possible. Therefore, in the present disclosure, the S content may be controlled to be 0.01% or less, more preferably 0.004% or less. In addition, the S content may be 0.0005% or more, more preferably 0.001% or more.

Al: 0.005 to 0.05%

[0025] Al is an element capable of inexpensively deoxidizing molten steel, and an upper limit of an Al content is controlled to be 0.05% in terms of securing impact toughness while sufficiently lowering yield strength. Alternatively, more preferably, the upper limit of the Al content may be controlled to 0.035%, and a lower limit of the Al content may be controlled to 0.005%, and more preferably 0.023%, in terms of securing the minimum deoxidation performance.

N: 0.005% or less (excluding 0%)

[0026] N is an element causing solid solution strengthening and is fixed to dislocations in a free state to increase yield strength and decrease elongation. In order to secure the effects described above, a case in which a N content is 0% is excluded (i.e., the N content exceeds 0%). However, the lower the N content, the better, so the N content is controlled to be 0.005% or less in terms of securing low yield strength. In addition, the N content may be 0.001% or more.

Nb: 0.04 to 0.15%

[0027] Nb is an important element in manufacturing TMCP steel, and is a very important element which prevents C from being fixed to dislocations by being precipitated in a form of NbC or NbCN. In addition, Nb dissolved during reheating

to a high temperature suppresses recrystallization of austenite, thereby exhibiting an effect of refining the structure.

[0028]   Meanwhile, in order to introduce deformed organic precipitates, it is necessary to secure a wide non-recrystallization region. As can be seen in FIG. 2, it is preferable to add 0.04% or more of Nb in terms of securing a temperature range of 50°C or higher between Ar3 and Tnr. In addition, in order to prevent deterioration of impact toughness due to coarsening of precipitates, it is preferable to add Nb to 0.15% or less.

[0029]   Specifically, FIG. 2 illustrates a graph of a change in recrystallization stop temperature (Tnr) according to an amount of Nb added to the steel material of the present disclosure. That is, in the case of ultra-low carbon steel in which the carbon content is controlled to be an ultra-low amount as in the present disclosure, Ar3 is very high at about 890°C, and the change in Ar3 is insignificant. Therefore, since the change value of Ar3 becomes a negligible level, it can be expressed by fixing Ar3 to about 890°C as shown in FIG. 2, and the recrystallization stop temperature (Tnr) of ultra-low carbon steel can be controlled to be high only when the Nb content is added at 0.04 to 0.15%. Therefore, as in the present disclosure, by controlling the Nb content to be within a range of 0.04 to 0.15%, it is possible to secure a difference between Tnr and Ar3 of ultra-low carbon steel at 50°C or higher, and due to this, deformed organic precipitates are generated finely, and C can be fixed as precipitates. Meanwhile, in terms of improving the effects described above, more preferably, a lower limit of the Nb content may be 0.07%, or an upper limit of the Nb content may be 0.1%.

Ti: 48/14×[N] to 0.05%

[0030]   Ti is an element that precipitates in a form of TiN, serving to prevent N from being fixed to dislocations. Therefore, in order to adhere N in steel in an appropriate range, considering the added N content (weight %), Ti should be added in an amount of 48/14×[N]% or more, where [N] refers to a content of nitrogen (weight %), or Ti should be added in an amount of 0.02% or more. Meanwhile, when Ti is excessively added, there is a concern that impact toughness may deteriorate due to coarsening of precipitates, so Ti may be controlled to be 0.05% or less in terms of securing impact toughness, and more particularly, Ti may be controlled to be 0.04% or less.

[0031]   That is, according to the present disclosure, N in steel may be fixed to as precipitates by controlling the Ti content to be within a range of 48/14×[N] to 0.05%, and C in steel may be fixed to as precipitates by controlling the Nb content to be within a range of 0.04 to 0.15%. Therefore, in the present disclosure, by optimizing the Ti and Nb contents, it is possible to control the deformed organic precipitates to be finely formed in an appropriate size, thereby effectively providing a steel material for a seismic damper having excellent low-temperature impact toughness while having low yield strength.

[0032]   Specifically, when C or N is in a free state, C or N is fixed to the dislocations to cause an upper yield point phenomenon, causing the yield strength to exceed 120 MPa. In addition, when coarse precipitates exist in a ferrite single structure, impact toughness deteriorates. However, in the case of being precipitated by strain induction during rolling, it is possible to suppress the deterioration in impact toughness due to the fine size and suppress expression of an upper yield point, so that a steel material having an ultra-low yield point may be provided. Therefore, according to the present disclosure, it is possible to provide a steel material having excellent low-temperature impact toughness having a Charpy impact transition temperature of -20°C or lower, while having a yield strength of 120MPa or less, which is very low.

[0033]   Meanwhile, according to an aspect of the present disclosure, although not particularly limited, the steel material for a seismic damper may have an R1 value defined by the following Relational Expression 1 of 0.8 or more, or more preferably, the R1 value have a range within 0.8 to 150. When the R1 value is 0.8 or more, a steel material having an ultra-low yield strength of 120MPa or less may be more effectively provided. In addition, when the R1 is 150 or less, Nb precipitates may be finely formed, so that more excellent impact toughness can be secured.

[Relational Expression 1]

$$R1 = [Nb]/[Si]$$

[0034]   In Relational Expression 1, [Nb] represents a content of Nb (weight %), and [Si] represents a content of Si(weight %).

[0035]   Meanwhile, in terms of improving the effects described above, more preferably, a lower limit of the R1 value defined by the Relational Expression 1 may be 3.33, or an upper limit of the R1 value may be 90.

[0036]   Alternatively, according to an aspect of the present disclosure, an R2 value defined by the following Relational Expression 2 of the steel material for a seismic damper may satisfy 0.8 or more. Alternatively, more preferably, the R2 value may be within a range of 0.8 to 200, and most preferably within a range of 4 to 200. When the R2 value is 0.8 or more, a steel material having a low yield strength of 120MPa or less may be more effectively provided. In addition, when the R2 value is 200 or less, Nb precipitates may be formed finely, so that better impact toughness may be secured.

[Relational Expression 2]

$$R2 = ([Ti]+[Nb])/[Si]$$

[0037] In Relational Expression 2, [Ti] represents a content of Ti(weight %), and [Si] represents a content of Si (weight %).

[0038] Meanwhile, in terms of improving the above-described effect, more preferably, a lower limit of the R2 value defined by the Relational Expression 2 may be 4.33, and an upper limit of the R2 value may be 130.

[0039] In the present disclosure, remainder is Fe. That is, in a steel material for a seismic damper, since in the common manufacturing process, unintended impurities may be inevitably incorporated from raw materials or the surrounding environment, the component may not be excluded. Since these impurities are known to any person skilled in the common manufacturing process, the entire contents thereof are not particularly mentioned in the present specification.

[0040] According to an aspect of the present disclosure, the steel material for a seismic damper has a ferrite single structure. By satisfying this, the steel material may serve as an earthquake damper by effectively adsorbing energy when an earthquake occurs.

[0041] In addition, according to an aspect of the present disclosure, an average ferrite grain size in a surface layer portion may be 150 to 500 um. When the average ferrite grain size in the surface layer portion is less than 150 um, a problem in that the yield strength exceeds a target yield strength may occur, and when average ferrite grain size exceeds 500 μm, a problem in that the yield strength of steel material for the damper is lower than the target strength may occur. Meanwhile, a lower limit of the average ferrite grain size in the surface layer portion may be more preferably 175 μm, and most preferably 200 um. Alternatively, an upper limit of the average ferrite grain size in the surface layer portion may be more preferably 310 μm, and most preferably 300 μm.

[0042] In addition, in the present specification, the surface layer portion refers to a region from a surface of the steel material to a region corresponding to 30% of a total thickness. Therefore, an inner region, other than the surface layer portion described later refers to a region excluding surface layer portions (upper surface layer portion and lower surface layer portion) respectively disposed in upper and lower portions in the thickness direction of the steel material.

[0043] According to an aspect of the present disclosure, the average ferrite grain size in the surface layer portion may be greater than an average ferrite grain size in an inner region, other than the surface layer portion, and more particularly, the average ferrite grain size may be 150 um or more greater than the average ferrite grain size in the inner region. By satisfying this, it is possible to express the effect of securing target yield strength.

[0044] Alternatively, according to an aspect of the present disclosure, the average ferrite grain size in the inner region, other than the surface layer portion, may be within a range of 10 to 50 um, more preferably within a range of 30 to 50 um. When the average ferrite grain size in the inner region is less than 10 um, a problem of exceeding the target yield strength may occur, and when the average ferrite grain size in the inner region exceeds 50 μm, a problem that the yield strength of the entire damper is lower than the target strength may occur.

[0045] Based on a cutting surface in the thickness direction of the steel material(i.e., a direction perpendicular to a rolling direction), the average ferrite grain size described above refers to an average value of values obtained by measuring an equivalent circle diameter of the crystal grains, and assuming that a spherical particle drawn with the longest length penetrating an inside of the crystal grain as a particle diameter, the average ferrite grain size described above is an average value of the measured grain sizes.

[0046] For a steel material of Inventive Example 1-2 to be described later, corresponding to an example of the present disclosure, an optical photograph of a microstructure captured with an optical microscope was shown in FIG. 1. As can be seen in FIG. 1, it can be confirmed that a ferrite grain size in the surface layer portion is greater than a ferrite grain size in an inner region other than the surface layer portion.

[0047] In addition, according to an aspect of the present disclosure, although not particularly limited, based on a thickness direction (a direction perpendicular to a rolling direction) of a steel material, a ratio (Ds/Dt) of a thickness Ds of the surface layer portion to a total thickness Dt of the steel material may be within a range of 0.1 to 0.3. As such, the ratio (Ds/Dt) of the surface layer portion of the total thickness of the steel material satisfies the range of 0.1 to 0.3, so as can be seen in FIG. 5, the steel material for a seismic damper having a very low yield strength of 120 MPa or less targeted in the present disclosure may be effectively provided.

[0048] Meanwhile, in the present disclosure, when the ratio (Ds/Dt) is less than 0.1, a problem in that sufficient energy as a damper may not be absorbed exceeding the target yield strength, may occur, and when the ratio (Ds/Dt) exceeds 0.3, as shown in FIG. 3, the yield strength is too low, so that a problem of performing safe support for a structure may occur.

[0049] Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the ratio (Ds/Dt) may be 0.14, or an upper limit of the ratio (Ds/Dt) may be 0.25.

[0050] In this case, it should be noted that the surface layer portion is a concept including all of the surface layer portions formed on each of the upper and lower portions of the steel material.

[0051]   According to an aspect of the present disclosure, a yield strength (YS) of the steel material for a seismic damper described above may be 120 MPa or less, and is not particularly limited, but may be more preferably in a range of 80 to 120 MPa. When the yield strength of the steel material exceeds 120 MPa, a problem in which energy may not be sufficiently absorbed when an earthquake occurs may occur, and when the yield strength of the steel material is less than 80MPa, a problem for stably maintaining a structure may occur.

[0052]   Hereinafter, a manufacturing method for a steel material for a seismic damper according to the present disclosure will be described in detail.

Slab heating operation

[0053]   A manufacturing method for a steel material for a seismic damper according to an aspect of the present disclosure may include an operation of reheating a steel slab satisfying the above-described composition, and the reheating may be performed to a temperature within a range of 1050 to 1250°C. In this case, a heating temperature of the steel slab is controlled to 1050°C or higher in order to sufficiently dissolve the carbonitride of Ti and/or Nb formed during casting. However, when heated to an excessively high temperature, there may be a concern of coarsening austenite, and it takes an excessive amount of time for a temperature of a surface after rough rolling to reach a cooling start temperature of a surface layer portion, so that the slab may be preferably heated at 1250 °C or lower. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of a reheating temperature of the slab may be 1075°C, or an upper limit of the reheating temperature of the slab may be 1125°C.

Rough rolling operation

[0054]   According to an aspect of the present disclosure, before a finish rolling operation to be described later, the heated steel slab may include an operation of performing rough rolling to adjust a shape of the slab, and a temperature during rough rolling may be controlled to be higher than a temperature (Tnr) at which recrystallization of austenite stops. It is possible to obtain an effect of destroying structural structures such as dentrite, or the like, formed during casting by rough rolling, and it is also possible to obtain an effect of reducing a size of austenite. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the rough rolling end temperature may be 995°C, or an upper limit of the rough rolling end temperature may be 1035°C.

Finish rolling operation

[0055]   An operation in which the heated steel slab described above (or rough-rolled bar) is finish rolled in a temperature range of Ar3 to 80°C or higher and Ar3 or lower is included. Subsequently, an operation of cooling, if necessary, after finish rolling may be included, and the cooling may be air cooling. Meanwhile, when the finish rolling temperature is lower than Ar3 to 80°C, a problem that a ferrite grain size inside the steel material becomes too fine may occur. In addition, when the finish rolling temperature exceeds Ar3, a problem in that the ferrite grain size inside the steel material become coarse may occur. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the finish rolling start temperature may be 955°C, or an upper limit of the finish rolling start temperature may be 980°C. In addition, a lower limit of the finish rolling end temperature may be 860°C, or an upper limit of the finish rolling end temperature may be 905°C.

Shot blasting treatment operation

[0056]   An operation of performing a shot blasting treatment on a surface of the finish-rolled steel material described above is included, wherein the shot blasting treatment may be performed so that a metallic ball or a non-metallic ball is rotated at a rate of 1,500 to 2,500 rpm, and sprayed on a surface of the plate material at a rate of 60 to 100 m/s. By performing the shot blasting treatment, coarse ferrite crystal grains may grow on the surface layer portion of the steel material, and a ratio of the thickness of the surface layer portion to the total thickness of the steel material can be increased to lower the yield strength.

[0057]   During the shot blasting treatment, when a rotational speed of the metallic ball or non-metallic ball is less than 1,500 rpm, a sufficient speed may not be secured, resulting in a problem of not securing the size of the ferrite grains on the surface layer portion, and when a rotational speed of the metallic ball or non-metallic ball exceeds 2,500 rpm, a problem may occur in a stable operation of a machine. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the rotational speed may be 1,550 rpm, or an upper limit of the rotational speed may be 2,350 rpm.

[0058]   In addition, when the spraying speed is less than 60 m/s, there may be a problem in that desired physical properties cannot be secured due to lack of effective stress application on a surface of the steel material, and when the

spraying speed exceeds 100 m/s, deep grooves are generated on the surface of the steel material, causing product defects. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the spraying speed may be 62 m/s, or an upper limit of the spraying speed may be 94 m/s.

[0059]   According to an aspect of the present disclosure, in the shot blasting treatment, a metallic ball or a non-metallic ball having an average diameter of 0.8 to 1.2 mm may be used. When a diameter of the ball is less than 0.8 mm, a problem of insufficient energy transmitted to a surface of the steel material may be caused, and when the diameter of the ball exceeds 1.2 mm, a problem of not uniformly transmitting energy to the surface of the steel material may be caused. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the average diameter of the metallic ball (or non-metallic ball) may be 0.9 mm, or an upper limit of the average diameter of the metallic ball (or non-metallic ball) may be 1.1 mm.

[0060]   In addition, according to an aspect of the present disclosure, the shot blasting treatment may be performed for 10 to 30 minutes. When the shot blasting treatment time is less than 10 minutes, a problem of insufficient energy transmitted to a surface of the steel material may be caused, and when the shot blasting treatment time exceeds 30 minutes, a problem of causing defects in the surface quality of the steel material may be caused. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the shot blasting treatment time may be 15 minutes, or an upper limit of the shot blasting treatment time may be 25 minutes.

Heat treatment operation

[0061]   According to an aspect of the present disclosure, although not particularly limited, after the shot blasting treatment operation, a heat treatment operation so that an LMP value defined by the following Relational Expression 3 satisfies a range of 23.5 to 24.5, may be further included.

$$[\text{Relational Expression 3}]$$

$$LMP = T \times [\log(t) + 20] / 1000$$

[0062]   In Relational Expression 3, T represents a heat treatment temperature, a unit thereof is °C, and t represents a heat treatment temperature, a unit thereof is minutes.

[0063]   In this case, since the value of Relational Expression 3,is a numerical value obtained empirically, a unit may not be particularly determined. That is, in the Relational Expression 3, it is sufficient when each unit of T and t described later is satisfied.

[0064]   According to an aspect of the present disclosure, the LMP value defined by the Relational Expression 3 described above may satisfy a range of 23.5 to 24. 5, so, as can be shown in FIG. 4,a thickness ratio of the surface layer portion with respect to the total thickness of the steel material may be controlled to be within a range of 0.1 to 0.3, so that a steel material having a target yield strength of 120 MPa or less (more preferably, within a range of 80 to 120 MPa) may be obtained.

[0065]   When a heat treatment is performed on a steel sheet subjected to shot blasting treatment, coarse ferrite grows from the surface layer portion of the steel material due to stress introduced into the surface layer portion. Thus, by controlling the heat treatment conditions to form coarse ferrite as shown in FIG. 1, on the surface layer portion of the steel material, a change in the yield strength of the steel material may be introduced.

[0066]   Meanwhile, although not particularly limited, in terms of improving the effects described above, a lower limit of the LMP value defined by the Relational Expression 3 may be 23.7, or an upper limit of the LMP value defined by the Relational Expression 3 may be 24.3.

[0067]   In addition, according to an aspect of the present disclosure, although not particularly limited, the heat treatment operation may be performed in a range of 850 to 900°C. When the heat treatment temperature is lower than 850°C, a problem of not securing sufficiently coarse ferrite growth may occur, and when the heat treatment temperature is higher than 900°C, a problem in that ferrite grains that are too more coarse than target ferrite grains are formed may occur. Meanwhile, although not particularly limited, in terms of improving the effects described above, more preferably, a lower limit of the heat treatment temperature may be 855°C, or an upper limit of the heat treatment temperature may be 880°C.

[0068]   In addition, according to an aspect of the present disclosure, the heat treatment time may be in a range of 5 to 30 minutes. Meanwhile, more preferably, a lower limit of the heat treatment time may be 10 minutes, or an upper limit of the heat treatment time may be 25 minutes.

Mode for Invention

[0069]   Hereinafter, the present disclosure will be specifically described through the following Examples. However, it

should be noted that the following examples are only for describing the present disclosure by illustration, and not intended to limit the right scope of the present disclosure. The reason is that the right scope of the present disclosure is determined by the matters described in the claims and reasonably inferred therefrom.

(Example)

[0070]   A steel slab having the alloy composition and properties illustrated in Table 1 below was prepared. In this case, a content of each component in Table 1 below is % by weight, and a balance thereof is Fe and inevitable impurities. That is, in the steel slabs (the balance being Fe) described in Table 1 below, Inventive Steels A to D illustrate an example matching a range of alloy compositions defined by the present disclosure, and Comparative Steels E to I illustrate an example deviating from the range of alloy compositions defined by the present disclosure.

[0071]   After reheating the prepared steel slab to a temperature within a range of 1050 to 1250°C, slab reheating - rough rolling -finish rolling was performed under the conditions illustrated in Table 2 below. Subsequently, after performing a shot blasting treatment for 15 minutes under the conditions of Table 3 using a metallic ball having an average diameter of 1.0 m, a heat treatment was performed to manufacture a steel material.

[Table 1]

Steel type	C	Si	Mn	P	S	Al	Ti	Nb	N	Ti*	Tnr [°C]	Ar3 [°C]
Inventive Steel A	0.0022	0.0003	0.1	0.0009	0.0003	0.03	0.02	0.08	0.0035	0.012	975	890
Inventive Steel B	0.0028	0.0002	0.11	0.001	0.0004	0.027	0.025	0.07	0.0017	0.006	965	892
Inventive Steel C	0.003	0.001	0.15	0.012	0.002	0.023	0.04	0.09	0.0025	0.009	980	895
Inventive Steel D	0.0045	0.03	0.2	0.013	0.0003	0.035	0.03	0.1	0.0032	0.011	987	898
Comparative Steel E	0.01	0.0005	0.13	0.014	0.0002	0.035	0.025	0.03	0.0038	0.013	926	875
Comparative Steel F	0.004	0.15	0.25	0.013	0.001	0.04	0.016	0.05	0.0021	0.007	955	896
Comparative Steel G	0.0025	0.0003	0.15	0.011	0.0003	0.024	0.035	0.17	0.0015	0.005	1,007	891
Comparative Steel H	0.0032	0.00015	0.21	0.016	0.0004	0.03	0.056	0.07	0.0021	0.007	967	897
Comparative Steel I	0.0015	0.00013	0.18	0.015	0.0002	0.025	0.04	0.06	0.0023	0.008	961	898

[0072] In Table 1, Ti* represents a value of 48/14×N (weight %).

[Table 2]

Division	Experimental Example	Slab reheating - Rough rolling conditions				Finish rolling	
		Produet thickness [mm]	Slab thickness [mm]	Reheating extraction temperature [°C]	Rough rolling end temperature [°C]	Start temperature [°C]	End temperature [°C]
Inventive Steel A	Example 1-1	25	285	1085	1005	970	875
	Example 1-2	15	285	1110	1035	960	860
	Reference Example 1	35	275	1105	1075	955	875
Inventive Steel B	Example 2-1	25	280	1095	995	960	880
	Example 2-2	20	285	1125	1005	955	876
	Reference Example 2	25	245	1055	975	975	915
Inventive Steel C	Example 3-1	20	270	1095	1003	979	905
	Example 3-2	15	280	1075	997	965	896
	Reference Example 3	12	260	1120	1078	970	880
Inventive Steel D	Example 4-1	35	270	1125	997	975	883
	Example 4-2	20	265	1115	1010	980	875
	Reference Example 4	27	275	1130	995	970	<u>910</u>
Comparative Steel E	Comparative Example 1	35	255	1080	985	925	876
Comparative Steel F	Comparative Example 2	19	275	1125	995	915	865
Comparative Steel G	Comparative Example 3	25	285	1130	993	920	870
Comparative Steel H	Comparative Example 4	20	290	1105	985	955	880
Comparative Steel I	Comparative Example 5	25	285	1085	1005	970	875

[Table 3]

Divisio n	Experimen tal Example	Shot blasting		Heat treatment conditions		LMP	Remarks
		Rotat ional speed [rpm]	Sprayi ng speed [m/s]	Tempe ratur e [°C]	Time [min.]		
Inventi ve Steel A	Example 1-1	1600	64	860	15	24	Recommen ded conditio ns
	Example 1-2	1800	72	875	15	24.3	Recommended conditio ns
	Reference Example 1	2100	84	890	55	25.3	Exceedin g LMP
Inventi ve Steel B	Example 2-1	1950	78	855	10	23.7	Recommen ded conditio ns
	Example 2-2	1700	68	860	17	24.1	Recommen ded conditio ns
	Reference Example 2	1850	74	895	30	25.1	Exceedin g LMP
Inventi ve Steel C	Example3-1	2150	86	875	5	23.8	Recommen ded conditio ns
	Example 3-2	2000	80	855	25	24.1	Recommen ded conditio ns
	Reference Example 3	1650	66	895	60	25.4	Exceedin g LMP
Inventi ve Steel D	Example4-1	2350	94	860	12	23.9	Recommen ded conditio ns
	Example 4-2	1550	62	880	10	24.2	Recommen ded conditio ns
	Reference Example 4	1680	67	868	45	24.7	Exceedin g LMP
Compara tive Steel E	Comparati ve Example 1	1870	75	865	15	24.1	Recommen ded conditio ns
Compara tive Steel F	Comparati ve Example 2	1930	77	871	10	24	Recommen ded conditio ns
Compara tive Steel G	Comparati ve Example 3	2250	90	880	12	24.3	Recommen ded conditio ns
Compara tive Steel H	Comparati ve Example 4	2355	94	868	15	24.2	Recommen ded conditio ns
Compara tive Steel I	Comparati ve Example 5	1895	76	860	15	24	Recommen ded conditio ns

[0073]   After manufacturing a steel material under the conditions described in Tables 2 and 3 above, the steel sheet thus obtained was polishing-etched and then observed with an optical microscope, so that it was confirmed that the steel material has a ferrite single structure.

[0074]   In addition, the results of measuring an average grain size, yield strength (YS), tensile strength (TS), and Charpy impact transition temperature for each of the steel material obtained from each Experimental Example in a surface layer portion and an inner region, other than the surface layer portion were shown in Table 4 below.

[0075]   In this case, the average grain size was measured using a line measurement method, and a point at which yielding occurs using a tensile tester according to the ASTM standard was set to be a yield strength and a strength when

necking occurs was set to be a tensile strength.For a Charpy impact transition temperature, an impact absorption energy was measured using a Charpy impact tester and a temperature at which fracture transitions from ductility to brittleness was shown.

[Table 4]

Steel composition	Experimental Example	Average ferrite grain size [μm]		Thickness ratio of upper and lower surface layer portions to total thickness of steel material	YS [MPa]	TS [MPa]	Charpy impact transition temperature [°C]
		Surface layer portion	Inner region other than surface layer portion				
Inventive Steel A	Example 1-1	210	37	0.2	98	247	-45
	Example 1-2	275	42	0.25	89	257	-50
	Reference Example 1	<u>730</u>	<u>65</u>	<u>0.45</u>	<u>65</u>	235	-35
Inventive Steel B	Example 2-1	175	25	0.14	112	289	-38
	Example 2-2	310	40	0.22	95	250	-37
	Reference Example 2	<u>750</u>	55	<u>0.08</u>	<u>68</u>	275	-40
Inventive Steel C	Example 3-1	182	32	0.16	107	285	-37
	Example 3-2	305	41	0.22	95	260	-41
	Reference Example 3	<u>820</u>	<u>75</u>	<u>0.47</u>	<u>64</u>	225	-28
Inventive Steel D	Example 4-1	190	34	0.18	103	285	-37
	Example 4-2	285	39	0.23	93	292	-51
	Reference Example 4	<u>710</u>	<u>51</u>	<u>0.07</u>	<u>77</u>	302	-41
Comparative Steel E	Comparative Example 1	240	38	0.22	<u>130</u>	298	-26
Comparative Steel F	Comparative Example 2	195	35	0.2	<u>135</u>	289	-21
Comparative Steel G	Comparative Example 3	305	41	0.25	89	275	<u>-12</u>
Comparative Steel H	Comparative Example 4	291	43	0.23	93	270	-5
Comparative Steel I	Comparative Example 5	180	35	0.2	<u>135</u>	296	-23

[0076] In Table 4 above, in Examples 1-1, 1-2, 2-1, 2-2, 3-1, 3-2, 4-1 and 4-2 satisfying both the steel composition and manufacturing conditions of the present disclosure, a thickness ratio of the upper and lower surface layer portions to the total thickness of the steel material was in a range of 0.1 to 0.3, and the physical properties of the steel material all satisfied the yield strength of 80 to 120 MPa and the Charpy impact transition temperature of -20 °C or lower.

[0077] Meanwhile, Reference Examples 1 to 4 illustrate a case of satisfying the steel composition of the present disclosure, but deviating from the manufacturing conditions. Thereamong, Reference Examples 1 to 4 illustrate a case in which the LMP exceeds 24.5. Reference Examples 1 to 4 illustrate a case of deviating from the range of 0.1 to 0.3, which is the thickness ratio of the surface layer portion, and the yield ratios were all less than 80 MPa.

[0078] In addition, in Comparative Example 1, C exceeded the upper limit of the content specified in the present disclosure, and the yield strength exceeded 120 MPa. In Comparative Example 2, Si, a solid solution strengthening element, exceeds the upper limit of the content specified in the present disclosure, and the yield strength exceeded 120 MPa. In Comparative Example 3, when Nb was added excessively, the impact toughness was deteriorated due to the formation of coarse precipitates, and the Sharpie impact transition temperature exceeded -20°C. Comparative Example 4 illustrates a case of satisfying all the manufacturing conditions of the present disclosure, but a content of Ti exceeded the upper limit specified in the present disclosure, and the Charpy impact transition temperature exceeded -20°C due to the formation of coarse precipitates. Comparative Example 5 illustrates a case of satisfying all the manufacturing conditions of the present disclosure, but the content of Ti was less than the lower limit specified in the present disclosure, and in Comparative Example 5, it was insufficient to precipitate free N as a nitride due to the insufficient Ti content, and a yield point phenomenon was expressed, and the yield strength exceeded 120 MPa.

[0079] While example 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 disclosure as defined by the appended claims.

Claims

1. A steel material for a seismic damper, comprising by weight:

   0.006% or less of C, 0.05% or less of Si, 0.3% or less of Mn, 0.02% or less of P, 0.01% or less of S, 0.005 to 0.05% of Al, 0.005% or less of N, 48/14×[N] to 0.05% of Ti, where [N] refers to a weight of nitrogen (weight %), and 0.04 to 0.15% of Nb, with a balance of Fe and other unavoidable impurities, having a ferrite single structure,
   wherein an average ferrite grain size in a surface layer portion from a surface thereof to a region corresponding to 30% of the total thickness is 150 to 500 μm.

2. The steel material for a seismic damper of claim 1, wherein an average ferrite grain size in an inner region other than the surface layer portion is 10 to 60 μm.

3. The steel material for a seismic damper of claim 1, wherein an R1 value defined by the following Relational Expression 1 is within a range of 0.8 to 150,

   [Relational Expression 1]

   R1 = [Nb]/[Si]

   In Relational Expression 1, [Nb] represents a content of Nb (weight %) and [Si] represents a content of Si (weight %).

4. The steel material for a seismic damper of claim 1, wherein an R2 value defined by the following Relational Expression 2 is within a range of 4 to 200,

   [Relational Expression 2]

   R2 = ([Ti]+[Nb])/[Si]

   In the Relational Expression 2, [Ti] represents a content of Ti (weight %) and [Si] represents a content of Si (weight %).

5. The steel material for a seismic damper of claim 1, wherein a ratio (Ds/Dt) of a thickness Ds of the surface layer portion of a total thickness Dt of the steel material is within a range of 0.1 to 0.3.

6. The steel material for a seismic damper of claim 1, wherein the steel material has a yield strength of 120MPa or less.

7. A manufacturing method for a steel material for a seismic damper, comprising:

heating a steel slab including by weight: 0.006% or less of C, 0.05% or less of Si, 0.3% or less of Mn, 0.02% or less of P, 0.01% or less of S, 0.005 to 0.05% of Al, 0.005% or less of N, 48/14×[N] to 0.05% of Ti, where, [N] refers to a content of nitrogen (weight %), and 0.04 to 0.15% of Nb, with a balance of Fe and other unavoidable impurities, to a temperature within a range of 1050 to 1250°C;
subjecting the heated steel slab to finish rolling in a temperature range of Ar3-80°C or higher and Ar3 or lower; and
performing a shot blasting treatment operation on a surface of the finish-rolled steel material,
wherein the shot blasting treatment operation is performed so that a metallic ball or a non-metallic ball is rotated at a rate of 1500 to 2500 rpm and sprayed on a surface of the plate material at a rate of 60 to 100 m/s.

8. The manufacturing method for a steel material for a seismic damper of claim 7, wherein the shot blasting treatment operation is performed for 10 to 30 minutes.

9. The manufacturing method for a steel material for a seismic damper of claim 7, wherein a diameter of the metallic ball or non-metallic ball is 0.8 to 1.2 mm.

10. The manufacturing method for a steel material for a seismic damper of claim 7, further comprising, after the shot blasting treatment operation:
performing a heat treatment so that an LMP value defined by the following Relational Expression 3 satisfies a range of 23.5 to 24.5,

[Relational Expression 3]

$$LMP = T \times [log(t)+20]/1000$$

in Relational Expression 3, T represents a heat-treatment temperature, wherein a unit thereof is°C. In addition, t represents a heat treatment time, wherein a unit thereof is minutes.

11. The manufacturing method for a steel material for a seismic damper of claim 10, wherein the heat treatment operation is performed in a range of 850 to 900°C.
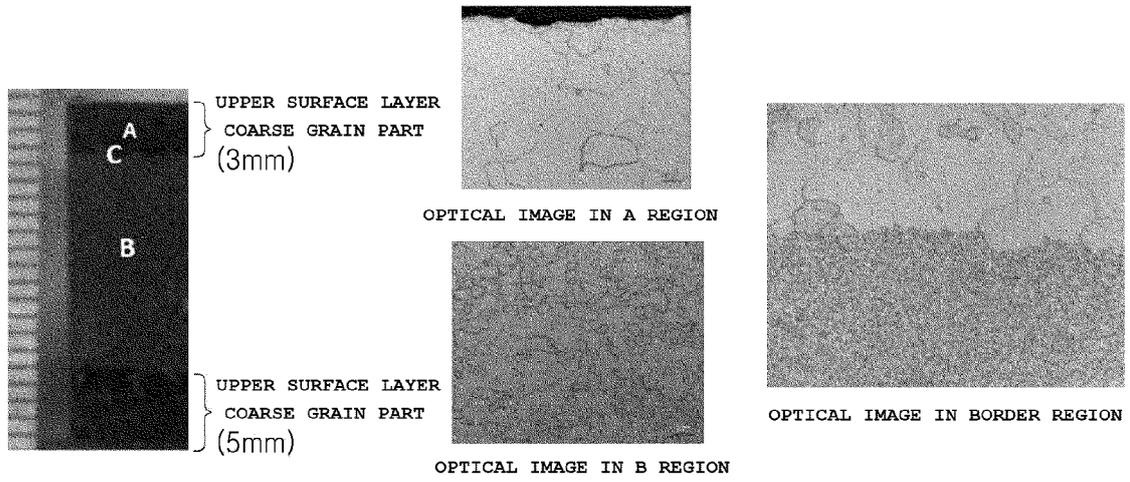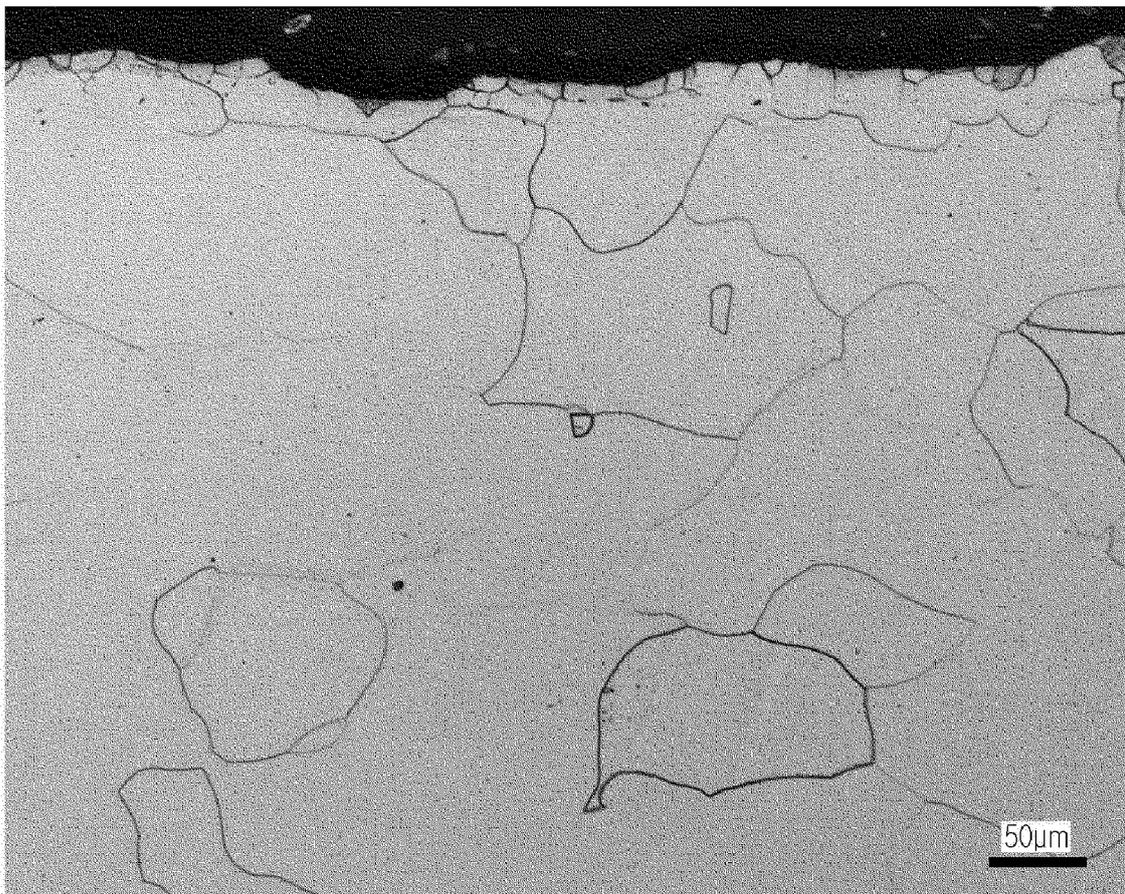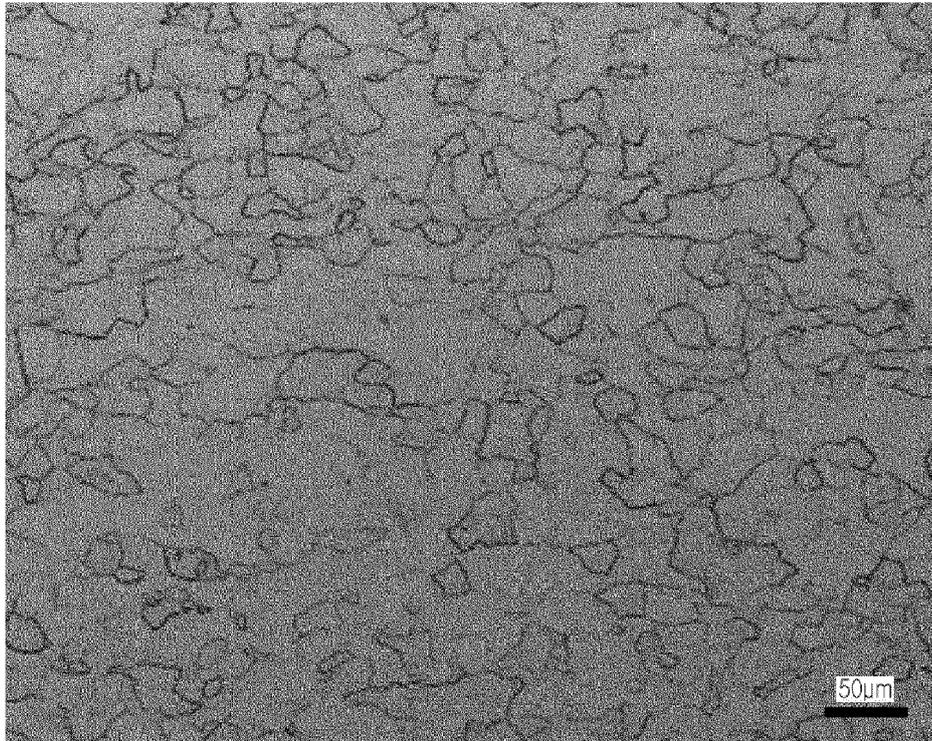
FIG. 1A

UPPER SURFACE LAYER
COARSE GRAIN PART
(3mm)

OPTICAL IMAGE IN A REGION

UPPER SURFACE LAYER
COARSE GRAIN PART
(5mm)

OPTICAL IMAGE IN B REGION

OPTICAL IMAGE IN BORDER REGION

FIG. 1B

50μm

FIG. 1C

FIG. 1D

FIG. 2

FIG. 3

FIG. 4

FIG. 5

YIELD STRENGTH , MPa

TARGET RANGE

RATIO OF DEPTHS OF UPPER AND LOWER COARSE SURFACE LAYERS
TO THICKNESS OF STEEL MATERIAL

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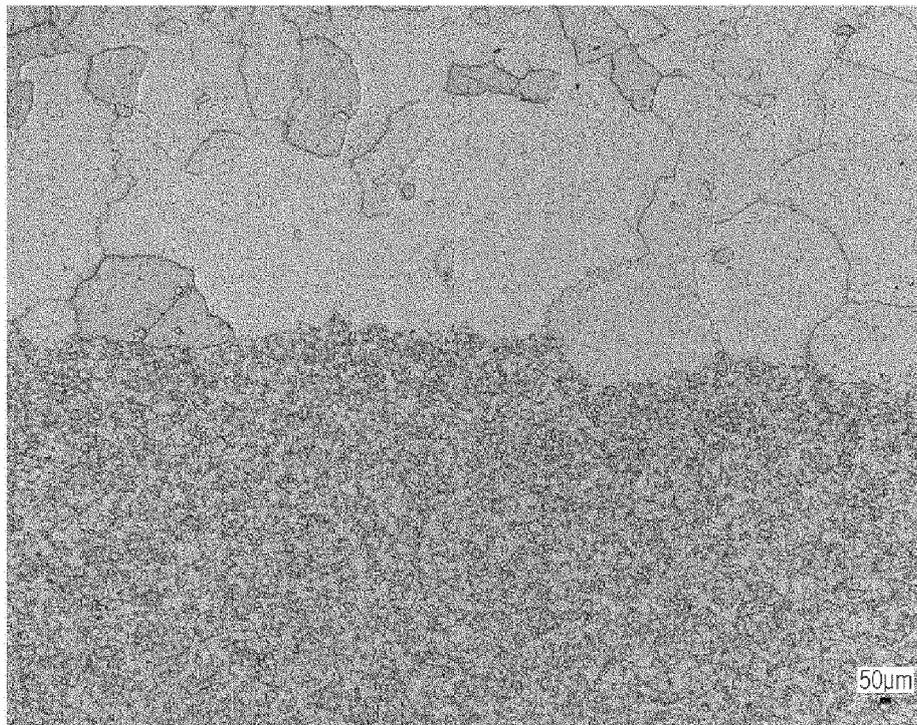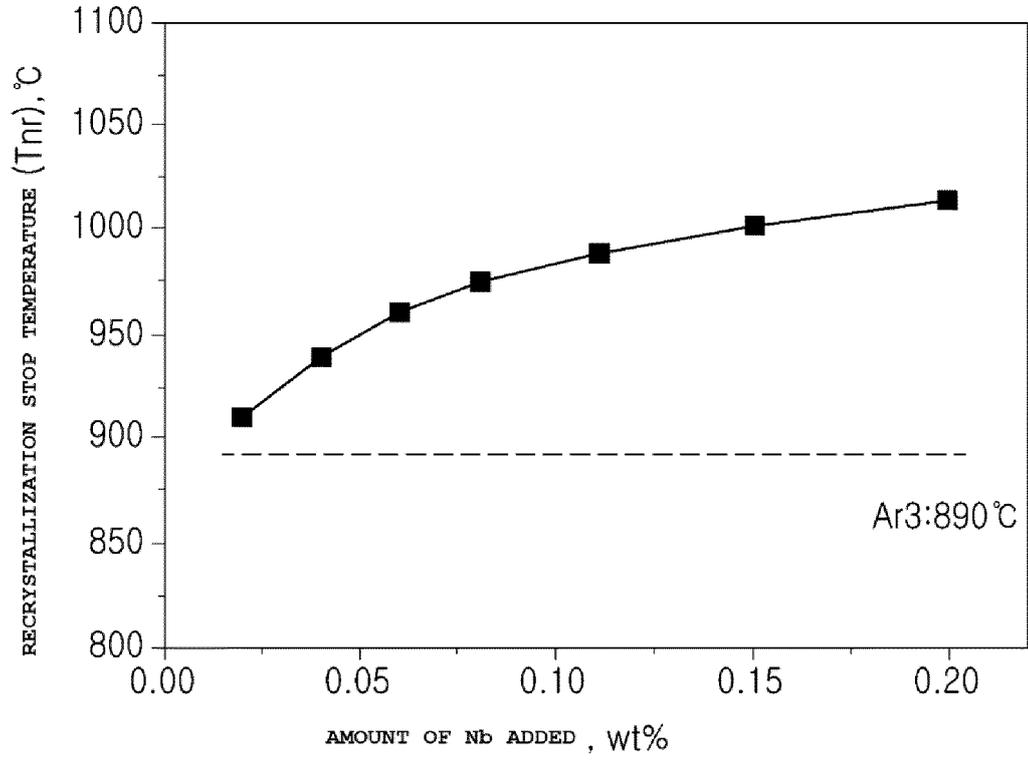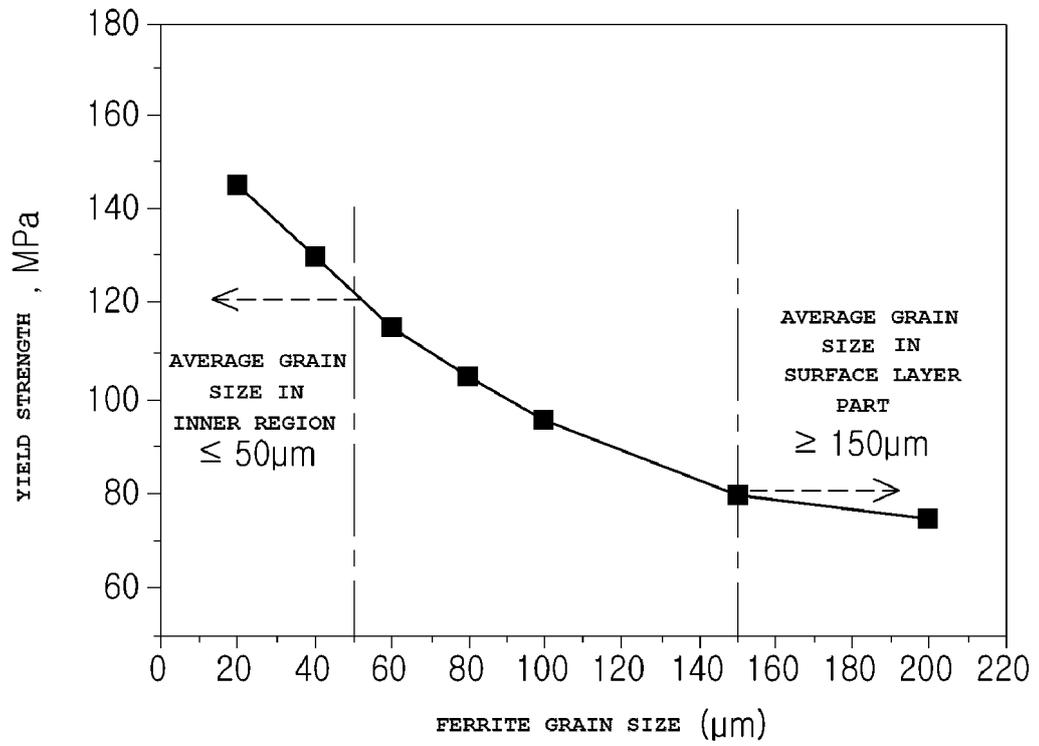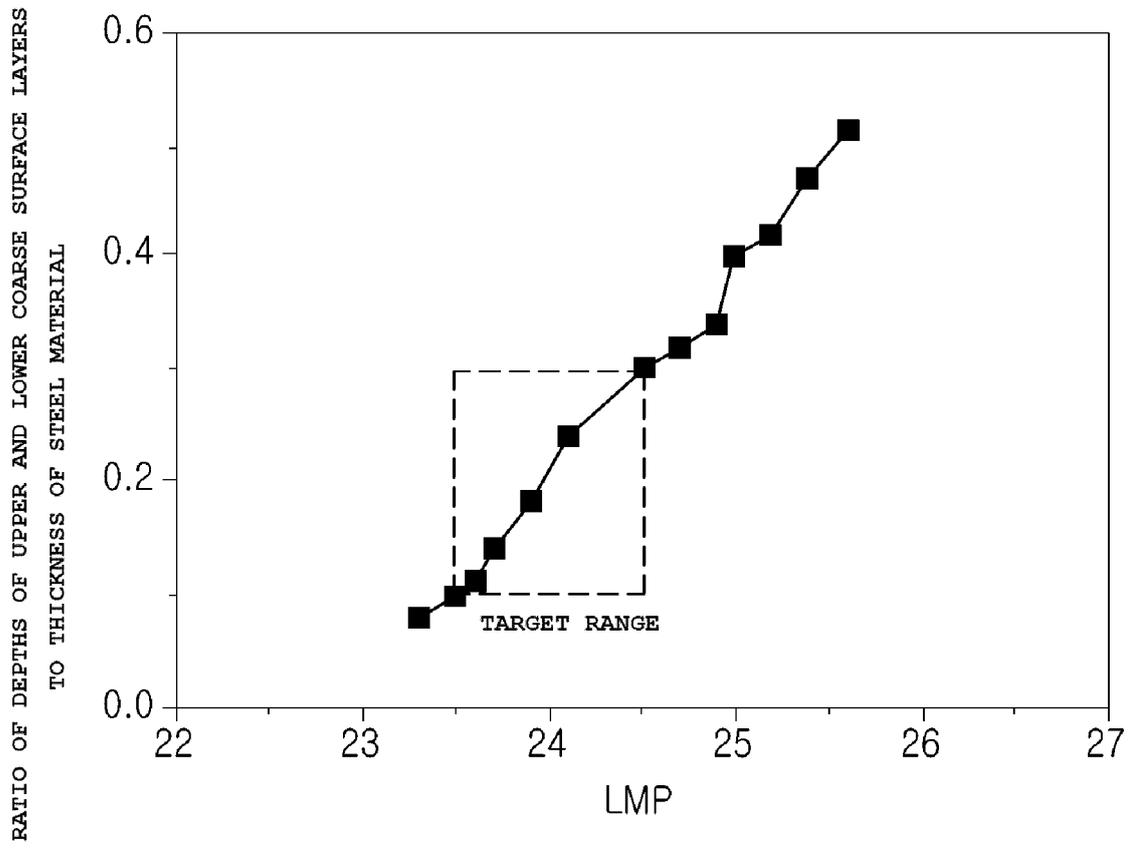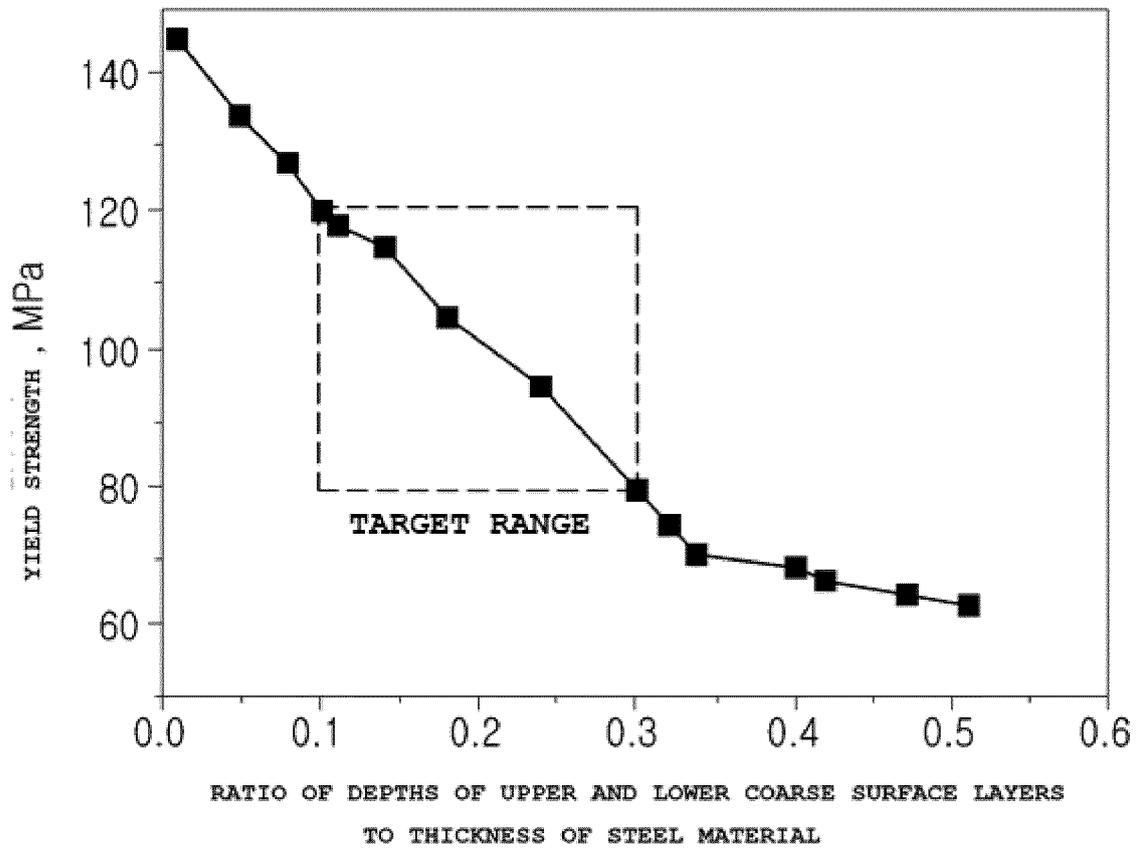
INTERNATIONAL SEARCH REPORT

</div>

	International application No.
	PCT/KR2021/017978

A.	**CLASSIFICATION OF SUBJECT MATTER**

C22C 38/00(2006.01)i; **C22C 38/02**(2006.01)i; **C22C 38/04**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/14**(2006.01)i; **C21D 7/06**(2006.01)i; **C21D 8/02**(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 38/00(2006.01); B21B 3/00(2006.01); B21B 45/00(2006.01); B21B 45/04(2006.01); B24C 1/10(2006.01); C21D 8/02(2006.01); C22C 38/12(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: 티타늄(Ti), 니오븀(Nb), 페라이트(ferrite), 쇼트 블라스트(shot blast), 항복 강도 (yield strength)

C.	**DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000-026936 A (NIPPON STEEL CORP.) 25 January 2000 (2000-01-25) See claims 1-3 and table 2.	1-5,7-9
A		6,10-11
A	JP 11-172367 A (NIPPON STEEL CORP.) 29 June 1999 (1999-06-29) See paragraphs [0040] and [0045] and claim 1.	1-11
A	KR 10-2010-0004806 A (POSCO) 13 January 2010 (2010-01-13) See paragraph [0049] and claim 1.	1-11
A	JP 2002-241897 A (SUMITOMO METAL IND. LTD.) 28 August 2002 (2002-08-28) See paragraph [0025] and claim 1.	1-11
A	JP 2007-284748 A (NIPPON STEEL CORP.) 01 November 2007 (2007-11-01) See claims 1-2.	1-11

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 March 2022	**11 March 2022**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208**	
Facsimile No. **+82-42-481-8578**	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2019)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2021/017978

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				CN	102083562	B	28 May 2014
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JP	2007-284748	A	01 November 2007	JP	4705508	B2	22 June 2011

Form PCT/ISA/210 (patent family annex) (July 2019)

REFERENCES CITED IN THE DESCRIPTION

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