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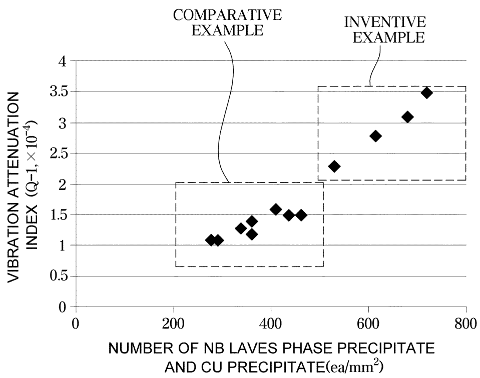
(54) **LOW CR FERRITIC STAINLESS STEEL HAVING EXCELLENT DAMPING CAPACITY AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed is a low-Cr ferritic stainless steel with excellent vibration attenuation ability that absorbs external vibration energy through precipitate control and a manufacturing method thereof.

The low-Cr ferritic stainless steel with excellent vibration attenuation ability according to an embodiment of the present disclosure includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less, S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, and includes 5×10^2/ mm^2 or more of Nb laves phase precipitates and Cu precipitates.

FIG. 1



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Description

[Technical Field]

[0001] The present disclosure relates to a low-Cr ferritic stainless steel with excellent vibration attenuation ability to absorb external vibration energy and a manufacturing method thereof.

[Background Art]

[0002] Ferritic stainless steel has excellent corrosion resistance while adding less expensive alloying elements, and has a higher price competitiveness than austenitic stainless steel. In particular, 9-14% of low-Cr ferritic stainless steel has superior cost competitiveness and is used in exhaust system parts (Muffler, Ex-manifold, Collector cone, etc.) corresponding to the exhaust gas temperature range of room temperature to 800°C. The steel plate for vehicle exhaust system must be capable of absorbing noise and vibration generated during engine or other driving, and must be able to withstand external environmental factors such as exhaust gas generated inside the vehicle, rain or fog. Therefore, sound absorption and corrosion resistance must be secured.

[0003] In order to solve this problem, in the case of high Cr ferritic stainless steel, attempts have been made to improve the vibration attenuation ability by controlling the number of precipitates, solid solution C, N, and the size and shape of inclusions, and the effects have been reported. However, there are no attempts and achievements to improve vibration attenuation ability by specializing in low-Cr ferritic stainless steel.

[Disclosure]

[Technical Problem]

[0004] The embodiments of the present disclosure are intended to provide a low-Cr ferritic stainless steel and a manufacturing method thereof maximizing the vibration attenuation ability by utilizing the Nb, Cu fine precipitated phase.

[Technical Solution]

[0005] In accordance with an aspect of the present disclosure, a low-Cr ferritic stainless steel with excellent vibration attenuation ability includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less, S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, and includes 5×10^2/ mm^2 or more of Nb laves phase precipitates and Cu precipitates.

[0006] The ferritic stainless steel may satisfy the following equation (1).

$$(1) \qquad (Nb+Cu)/Ti \geq 1.5$$

(Nb, Cu, Ti mean the content (% by weight) of each element)

[0007] The ferritic stainless steel may satisfy the following equation (2).

$$(2) \qquad Nb+Cu \leq 0.5$$

(Nb, Cu mean the content (% by weight) of each element)

[0008] The Nb Laves phase precipitate may be Fe_2Nb, and the size of the Nb Laves phase precipitate and the Cu precipitate may be 1 to 200nm.

[0009] The vibration attenuation index (Q-1) of the stainless steel may be 2.0×10^{-4} or more at 25°C, 2.5×10^{-4} or more at 300°C.

[0010] In accordance with an aspect of the present disclosure, a manufacturing method of a low-Cr ferritic stainless steel with excellent vibration attenuation ability includes: cold-rolling annealing a cold-rolled steel plate of a ferritic stainless steel comprising in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less, S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, at a temperature of (Ac1-10)°C or less; and quenching at 400 to 600°C and maintaining for 5 minutes or more.

[0011] The cold-rolled steel plate may satisfy the following equation (1).

$$(1) \qquad (Nb+Cu)/Ti \geq 1.5$$

(Nb, Cu, Ti mean the content (% by weight) of each element)

[0012] The cold-rolled steel plate may satisfy the following equation (2).

$$(2) \qquad Nb+Cu \leq 0.5$$

(Nb, Cu mean the content (% by weight) of each element)

[Advantageous Effects]

[0013] The low-Cr ferritic stainless steel according to an embodiment of the present disclosure can increase vibration attenuation ability by 100% or more through a sound absorption mechanism by the movement of solid solution C and N and a vibration attenuation mechanism through suppression of precipitation of carbonitrides.

[0014] In addition, the low-Cr ferritic stainless steel according to the embodiment of the present disclosure has excellent corrosion resistance, so that when used in vehicle exhaust system parts, etc., quietness and durability can be secured.

[Description of Drawings]

[0015]

FIG. 1 is a graph showing the correlation of the vibration attenuation index according to the number of Nb Laves phase precipitates and Cu precipitates.

FIG. 2 is a photograph showing the distribution of Nb Laves phase precipitates and Cu precipitates at the matrix interface.

[Best Mode]

[0016] A low-Cr ferritic stainless steel with excellent vibration attenuation ability according to an embodiment of the present disclosure includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less, S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, and includes 5×10^2/ mm^2 or more of Nb laves phase precipitates and Cu precipitates.

[0017] The ferritic stainless steel according to an embodiment of the present disclosure may satisfy the following equation (1).

$$(1) \qquad (Nb+Cu)/Ti \geq 1.5$$

[0018] Here, Nb, Cu, Ti mean the content (% by weight) of each element.

[Modes of the Invention]

[0019] Hereinafter, the embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The following embodiments are provided to transfer the technical concepts of the present disclosure to one of ordinary skill in the art. However, the present disclosure is not limited to these embodiments, and may be embodied in another form. In the drawings, parts that are irrelevant to the descriptions may be not shown in order to clarify the present disclosure, and also, for easy understanding, the sizes of components are more or less exaggeratedly shown.

[0020] Also, when a part "includes" or "comprises" an element, unless there is a particular description contrary thereto, the part may further include other elements, not excluding the other elements.

[0021] An expression used in the singular encompasses the expression of the plural, unless it has a clearly different meaning in the context.

[0022] The present inventors have conducted various studies in order to improve the vibration attenuation ability of low-Cr ferritic stainless steel, and have obtained the following knowledge.

[0023] The sound-absorbing mechanism (Snoek Effect) indicates that during vibration, solid solution C and N cause energy loss while changing their position in the lattice, and as a result, absorb sound. The sound-absorbing effect by solid solution C and N is proportional to the amount of solid solution C and N, and the vibration attenuation effect by magnetic domain wall becomes better as there are no factors that hinder the movement of the magnetic domain wall such as precipitate, dislocation, and internal stress.

[0024] In general, a trace amount of Ti and Nb is added to the ferritic stainless steel for exhaust system for corrosion resistance of the weld. In the case of such ferritic stainless steel with Ti and Nb added, a large amount of Ti(C,N) and Nb(C,N) carbonitrides are inevitably precipitated in the ferrite matrix of the surface layer. These Ti(C,N), Nb(C,N) precipitates are essentially inferior in the vibration attenuation ability of ferritic stainless steel because they inhibit the movement of the magnetic domain wall, which is one of the vibration attenuation mechanisms during vibration. In addition, since C and N are mostly combined with Nb and Ti in a precipitate state, there is relatively no solid solution C and N present in the ferrite matrix. Therefore, the sound absorption mechanism (Snoek Effect) due to the movement of solid solution C and N during vibration cannot be expected.

[0025] On the other hand, Nb is added for high temperature strength to ferritic stainless steel that is applied at high temperatures of 400°C or higher, and Cu is added as a solid solution strengthening element. In this case, a fine-sized Nb Laves Phase (Fe_2Nb) and Cu precipitated phase of 1 to 200 nm may be generated under specific heat treatment conditions, the interface between the coherent precipitated phase and the matrix reacts to external vibration and vibrates together, and by absorbing external vibration energy, the vibration attenuation ability can be increased. At this time, the effect is further increased when the Nb Laves phase or Cu is precipitated in a complex manner than when precipitated alone. However, when the size of the precipitate is coarsened to more than 200 nm, the coherency of the precipitate and the matrix decreases, and the number of precipitates decreases, so the effect of improving the vibration attenuation ability is rather offset. Therefore, the vibration attenuation ability can be maximized by precipitating fine Nb Laves-phase precipitates and Cu precipitates at the interface of the matrix.

[0026] A low-Cr ferritic stainless steel with excellent vibration attenuation ability according to an embodiment of the present disclosure includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less, S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, and includes 5×10^2/ mm^2 or more of Nb laves phase precipitates and Cu precipitates.

[0027] Hereinafter, the reason for the numerical limitation of the content of the alloy component element in the embodiment of the present disclosure will be described. Hereinafter, unless otherwise specified, the unit is% by weight.

[0028] The content of C is 0.005 to 0.01%.

[0029] C is a key element that causes sound absorption, and since the solid solution C continues to move from its original position in the lattice of the matrix to another position when the steel plate vibrates, energy loss occurs and sound absorption occurs. In general, as the solid solution C in the matrix increases, the sound absorption and vibration attenuation ability increases. However, when the content exceeds 0.01%, the concentration of solid solution C reaches its limit, and it combines with Cr to form $Cr_{23}C_6$ precipitates, which hinders the movement of the magnetic domain wall, and local Cr depletion within the matrix causes golden dust. Therefore, corrosion resistance is lowered.

[0030] The content of N is 0.005 to 0.01%.

[0031] Among the steels, N is a key element that causes sound absorption and vibration attenuation through the same mechanism as C. As the solid solution N in the matrix increases, the vibration attenuation ability increases. However, if it exceeds 0.01%, the concentration of solid solution N reaches its limit, it binds to Cr and generates Cr_2N precipitates, which hinders the movement of the magnetic domain wall, and local Cr depletion within the matrix causes golden dust. Therefore, corrosion resistance is lowered.

[0032] The precipitation of carbonitrides can be suppressed by increasing the solid solution C and N in the matrix by controlling the content of C+N to be less than or equal to 0.02%, and the vibration attenuation ability due to the smooth movement of the magnetic domain wall can be improved.

[0033] The content of Si is 0.1 to 0.9%.

[0034] Si is an element that acts as a deoxidizer in steel making, and contains 0.1% or more. However, when it is contained in a large amount, inclusions are generated due to Si oxide, and since such inclusions hinder the movement of the magnetic domain wall and thus inhibit vibration attenuation ability, the content is limited to 0.9% or less.

[0035] The content of Mn is 0.1 to 0.9%.

[0036] Mn serves to stabilize austenite. When it is contained in a large amount, the austenite-ferrite transformation point (Ac1) is lowered, and high temperature annealing capable of dissolving C and N after cold rolling becomes impossible, so the content is limited to 0.9% or less.

[0037] The content of Cr is 9 to 14%.

[0038] Cr increases the magnetostriction constant of the steel to further promote the movement of the magnetic domain wall compared to carbon steel when vibration occurs, and increases the vibration attenuation ability by the movement of the magnetic domain wall. It also plays a positive role in the vibration attenuation effect caused by C and N. However, if the Cr content exceeds 14%, because carbonitrides are easily formed by easily combining with C and N, the amount of solid solution C and N is lowered, and the precipitate interferes with the movement of the magnetic domain wall, the content is limited to the above range..

[0039] The content of Ni is 0.3% or less.

[0040] Ni may be contained in an amount of 0.1% as an impurity unavoidably included in steel by scrap melting, and its upper limit is limited to 0.3%.

[0041] The content of P is 0.04% or less.

[0042] P is an inevitable impurity contained in steel, and it is limited to 0.04% or less because it causes grain boundary corrosion during pickling or impairs hot workability. The preferred P content is 0.01 to 0.04%.

[0043] The content of S is 0.002% or less.

[0044] S is an inevitable impurity contained in steel, and its content is limited to 20 ppm or less because it segregates at grain boundaries and impairs hot workability.

[0045] The content of Ti is 0.15 to 0.3%.

[0046] Ti should be added in order to increase the corrosion resistance of the weld, so it is added at least 0.15%. However, since Ti combines with C and N to form Ti(C,N) precipitates to lower the amount of solid solution C and N, and Ti(C,N) precipitates hinder the movement of the magnetic domain wall, Ti makes the vibration attenuation ability inferior. Therefore, the content is limited to 0.3% or less.

[0047] The content of Nb is 0.15 to 0.3%.

[0048] Nb is also an element that is essentially added to increase the corrosion resistance of the weld. When Nb satisfies the appropriate component conditions and heat treatment conditions, fine laves phase precipitates are generated, which helps to improve the vibration attenuation ability, and is added at least 0.15%. However, since Nb combines with C and N to form Nb(C,N) precipitates to lower the amount of solid solution C and N, and Nb C,N) precipitates hinder the movement of the magnetic domain wall, Nb makes the vibration attenuation ability inferior. Therefore, the content is limited to 0.3% or less.

[0049] The content of Cu is 0.15 to 0.3%.

[0050] Cu generates fine precipitates by appropriate heat treatment and helps to improve vibration attenuation ability, so it is added at least 0.15%. However, if the content of Cu is high, the hot workability at high temperature may be impaired, so the content is limited to 0.3% or less.

[0051] The content of Al is 0.01 to 0.05%.

[0052] Al combines with N to form AlN precipitates to lower the amount of solid solution N, and because AlN precipitates hinder the movement of the magnetic domain wall, it makes the vibration attenuation ability inferior. In addition, Al is an alloy component that is added as a deoxidizing agent during steelmaking, but when added in a large amount, it exists as non-metallic inclusions and causes sliver defects in the cold-rolled strip, so its content is limited to 0.01 to 0.05%.

[0053] The remainder of the ferritic stainless steel except for the above alloying elements is made of Fe and other inevitable impurities.

[0054] The low-Cr ferritic stainless steel according to an embodiment of the present disclosure may satisfy equation (1) below.

(1) $(Nb+Cu)/Ti \geq 1.5$

[0055] As the content of Ti increases, the formation of Ti(C,N) precipitates increases to lower the solid solution C and N, and the vibration attenuation ability decreases because the precipitates themselves interfere with the movement of the magnetic domain wall. In order to overcome this, it is necessary to increase the Nb+Cu content so that the vibration attenuating effect by the fine Nb Laves phase precipitate and Cu precipitate should be increased. When the above equation (1) is satisfied together with the above-described alloy component composition, the vibration attenuation ability can be significantly improved compared to the existing one.

[0056] The low-Cr ferritic stainless steel according to an embodiment of the present disclosure may satisfy equation (2) below.

(2) $Nb+Cu \leq 0.5$

[0057] When the content of Nb+Cu becomes higher than necessary, coarsening of precipitates easily occurs. In this case, the coherent between the precipitate and the matrix decreases, and the number of precipitates and the total interface area are reduced, so that the vibration attenuation effect due to the Nb Laves-phase precipitate and the Cu precipitate is difficult to develop. Therefore, the Nb+Cu content is limited to 0.5% or less.

[0058] The Nb Laves phase precipitate is Fe_2Nb, and the size of the Nb Laves phase precipitate and the Cu precipitate may be 1 to 200 nm. As described above, when the size of the Nb Laves-phase precipitate and the Cu precipitate are coarse, the number of precipitates is relatively small compared to the fine precipitates, and the coherency between the precipitate and the matrix interface is poor, so that the vibration attenuation effect is small. Therefore, in order to maximize the vibration attenuation ability, it is desirable to control the size of the precipitate to 200 nm or less.

[0059] The low-Cr ferritic stainless steel of present disclosure including $5\times10^2/\ mm^2$ or more of Nb laves phase precipitates and Cu precipitates of 200 nm or less has a vibration attenuation index (Q-1) of 2.0×10^{-4} or more at 25°C and 2.5×10^{-4} or more at 300°C, which can exhibit excellent vibration attenuation.

[0060] Next, a method of manufacturing a low-Cr ferritic stainless steel with excellent vibration attenuation ability according to an embodiment of the present disclosure will be described.

[0061] The manufacturing method of the low-Cr ferritic stainless steel with excellent vibration attenuation ability of the present disclosure can be manufactured into a cold-rolled steel plate through a conventional manufacturing process, and includes cold-rolling annealing a cold-rolled steel plate of the ferritic stainless steel containing the above-described alloy component composition at a temperature of (Ac1-10) °C or less; and quenching at 400 to 600°C and maintaining for 5 minutes or more.

[0062] For example, the slab including the above-described alloy component composition may be hot-rolled, the hot-rolled hot-rolled steel plate may be annealed, and cold-rolled to form a cold-rolled steel plate.

[0063] Cold-rolled steel plate is cold-rolled and annealed in a temperature range below the temperature 10°C lower than the austenite-ferrite transformation temperature (Ac1). Since some austenite phase exists in the Cr content range of the present disclosure, the annealing temperature is limited to (Ac1-10) °C or less to prevent reverse transformation. Annealing is performed so that C and N are sufficiently dissolved in the matrix within the above temperature range.

[0064] In addition, in order to suppress the formation of Cr carbonitrides, quenching is required in a temperature range of 400 to 600°C after cold rolling annealing, and by increasing the number of fine Nb Laves phase precipitates and Cu precipitates through heat treatment maintained in the above temperature range for 5 minutes or more, vibration attenuation ability can be maximized.

[0065] At this time, when the Nb+Cu content according to equation (2) exceeds 0.5%, as compared to the Nb Laves phase precipitate and Cu precipitate, which are additionally generated by the heat treatment, the pre-precipitated precipitates are coarsened, so that the total number of precipitates may be reduced. Therefore, when the Nb+Cu content exceeds 0.5%, it is preferable not to perform additional heat treatment after cold rolling annealing.

[0066] Hereinafter, it will be described in more detail through a preferred embodiment of the present disclosure.

Example

[0067] The vibration attenuation ability was measured through IMCE's "RFDA LTVP800" equipment. The above equipment generates vibration at a natural frequency by applying a shock of a certain force to a sample of 80 mm (length) * 20 mm (width), and then measures the degree of attenuation of the sound to obtain the vibration attenuation index (Q-1). The higher the vibration attenuation index, the faster the vibration is attenuated. In other words, it has excellent vibration attenuation ability. In the above equipment, the vibration attenuation index can be obtained for a temperature range of 25 ~ 800°C. For each of the final heat-treated alloys, the vibration attenuation index at room temperature (25°C) and 300°C was calculated. The natural frequency was 1 kHz.

[0068] The number of Nb Laves phase precipitates and Cu precipitates was measured for only precipitates having a size of 200 nm or less.

<table 1>

	C	N	Si	Mn	Cr	Ti	Nb	Cu	(Nb+Cu) /Ti	(Nb+Cu)
Inventive example1	0.00 7	0.008	0.27	0.41	11.7	0.19	0.18	0.23	2.16	0.41
Inventive example 2	0.00 6	0.007	0.35	0.28	12.5	0.16	0.22	0.27	3.06	0.49
Comparative example1	0.00 5	0.009	0.45	0.33	10.5	0.11	0.12	0.12	2.18	0.24
Comparative example 2	0.00 8	0.006	0.29	0.29	13.1	0.38	0.34	0.32	1.74	0.66
Comparative example 3	0.00 5	0.006	0.23	0.22	11.2	0.25	0.16	0.17	1.32	0.33
Comparative example 4	0.00 9	0.009	0.17	0.53	11.8	0.16	0.28	0.27	3.44	0.55

<table 2>

	After annealing, maintain 500°C for 5 minutes	Total amount of Nb and Cu precipitates (ea/mm^2)	vibration attenuation index (Q-1, $\times 10^{-4}$) @25°C	vibration attenuation index (Q-1, $\times 10^{-4}$) @300°C
Inventive example 1	×	528	2.3	2.5
	○	679	3.1	3.3

(continued)

	After annealing, maintain 500°C for 5 minutes	Total amount of Nb and Cu precipitates (ea/mm^2)	vibration attenuation index (Q-1, $\times 10^{-4}$) @25°C	vibration attenuation index (Q-1, $\times 10^{-4}$) @300°C
Inventive example 2	×	613	2.8	3.1
	○	718	3.5	3.7
Comparative example 1	×	289	1.1	1.2
	○	360	1.2	1.3
Comparative example 2	×	336	1.3	1.4
	○	435	1.5	1.6
Comparative example 3	×	359	1.4	1.5
	○	460	1.5	1.7
Comparative example 4	×	410	1.6	1.6
	○	275	1.1	1.2

[0069] FIG. 1 is a graph showing the correlation of the vibration attenuation index according to the number of Nb Laves phase precipitates and Cu precipitates. The results of analyzing the data of the inventive examples and comparative examples of Tables 1 to 2 with reference to FIG. 1 are as follows.

[0070] Looking at Invention Examples 1 and 2, by satisfying both the component range of the present disclosure and Equations (1) and (2), even without heat treatment at 500° C for 5 minutes or more after annealing, the total amount of Nb Laves phase precipitate and Cu precipitate is 500 or more per mm^2, and at room temperature, the vibration attenuation index (Q-1) was measured to be 2.3×10^{-4} or higher. In particular, in the case of performing heat treatment, it was found that the total amount of precipitates increased by 100 to 150 to increase 15 to 30%. Accordingly, the vibration attenuation index (Q-1) was also increased by 20 to 35% and was measured to be 3.1×10^{-4} or more.

[0071] Comparative Example 1 satisfies equations (1) and (2), but the content of Ti, Nb, and Cu did not reach 0.15%, so even after annealing and additional heat treatment at 500°C, the total amount of precipitates was as small as 360 /mm^2. It was found that this was due to insufficient Nb and Cu content for forming the Nb Laves phase precipitate and Cu precipitate.

[0072] In Comparative Example 2, the content of Ti, Nb, and Cu all exceeded 0.3%, so that the Nb+Cu value in equation (2) exceeded 0.5%, and accordingly, even after annealing and additional heat treatment at 500°C, the total amount of precipitates did not reach 500 /mm^2 Equation (1) is satisfactory, but since the content of Ti and Nb is high, forming carbonitrides with C and N, lowering the solid solution C and N, and since the carbonitride itself interferes with the movement of the magnetic domain wall, it was confirmed that the vibration attenuation ability was deteriorated. In addition, it was estimated that the total amount of precipitates was lower than that of the inventive example as the precipitates became coarse due to the high content of Cu as well as Nb.

[0073] Comparative Example 3 satisfies all the component ranges of the present disclosure including Ti, Nb, and Cu, but is not satisfied with equation (1) due to the high content of Ti compared to Nb+Cu, and accordingly, a large amount of Ti(C,N) carbonitrides was precipitated. FIG. 2 is a photograph showing the distribution of Nb Laves phase precipitates and Cu precipitates at the matrix interface of Comparative Example 3. It can be seen that TiN was generated due to the high Ti content. These TiN precipitates not only lower the solid solution C and N, but also the precipitates themselves hinder the movement of the magnetic domain wall. The vibration attenuation index was also measured to be 1.7×10^{-4} or less even after additional heat treatment.

[0074] Comparative Example 4 satisfies the component range of the present disclosure including Ti, Nb, and Cu and equation (1), but dissatisfied with the equation (2) due to the high Nb+Cu content. In Comparative Example 4, the content of Nb+Cu was high at 0.55%, so it was estimated that the Nb Laves phase precipitate and the Cu precipitate were coarsened. In particular, as a result of heat treatment at 500°C after annealing, the total amount of precipitates having a size of 200 nm or less was reduced, which was confirmed to be due to the coarsening of the precipitates. When the precipitate becomes coarse, the coherency of the matrix interface and the interface area are lowered, thereby reducing the vibration attenuation effect. After the additional heat treatment of Comparative Example 4, the vibration attenuation index was the lowest despite satisfying the component range of the present disclosure.

[0075] As described above, although exemplary embodiments of the present disclosure have been described, the present disclosure is not limited thereto, and a person with ordinary knowledge in the relevant technical field may not depart from the concept and scope of the following claims. It will be appreciated that various changes and modifications are possible.

[Industrial Applicability]

[0076] The ferritic stainless steel according to the present disclosure maximizes vibration attenuation ability by utilizing Nb and Cu fine precipitation phases, thereby securing quietness and durability of vehicle exhaust system parts.

Claims

1. A low-Cr ferritic stainless steel with excellent vibration attenuation ability, the ferritic stainless steel comprising, in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less , S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, and
   wherein the ferritic stainless steel comprises $5\times10^2/\,mm^2$ or more of Nb laves phase precipitates and Cu precipitates.

2. The ferritic stainless steel of claim 1, wherein the ferritic stainless steel satisfies the following equation (1)

   (1) $(Nb+Cu)/Ti \geq 1.5$

   (Nb, Cu, Ti mean the content (% by weight) of each element)

3. The ferritic stainless steel of claim 1, wherein the ferritic stainless steel satisfies the following equation (2)

   (2) $Nb+Cu \leq 0.5$

   (Nb, Cu mean the content (% by weight) of each element)

4. The ferritic stainless steel of claim 1, wherein the Nb Laves phase precipitate is Fe_2Nb, and
   the size of the Nb Laves phase precipitate and the Cu precipitate is 1 to 200nm.

5. The ferritic stainless steel of claim 1, wherein a vibration attenuation index (Q-1) of the stainless steel is 2.0×10^{-4} or more at 25°C, 2.5×10^{-4} or more at 300°C.

6. A manufacturing method of a low-Cr ferritic stainless steel with excellent vibration attenuation ability, the manufacturing method comprising:

   cold-rolling annealing a cold-rolled steel plate of a ferritic stainless steel comprising in percent (%) by weight of the entire composition, C: 0.005 to 0.01%, N: 0.005 to 0.01%, Si: 0.1 to 0.9%, Mn: 0.1 to 0.9%, Cr: 9 to 14%, Ni: 0.3% or less, P: 0.04% or less, S: 0.002% or less, Ti: 0.15 to 0.3%, Nb: 0.15 to 0.3%, Cu: 0.15 to 0.3%, Al: 0.01 to 0.05%, the remainder of iron (Fe) and other inevitable impurities, at a temperature of (Ac1-10)°C or less; and
   quenching at 400 to 600°C and maintaining for 5 minutes or more.

7. The manufacturing method of claim 6, wherein the cold-rolled steel plate satisfies the following equation (1)

   (1) $(Nb+Cu)/Ti \geq 1.5$

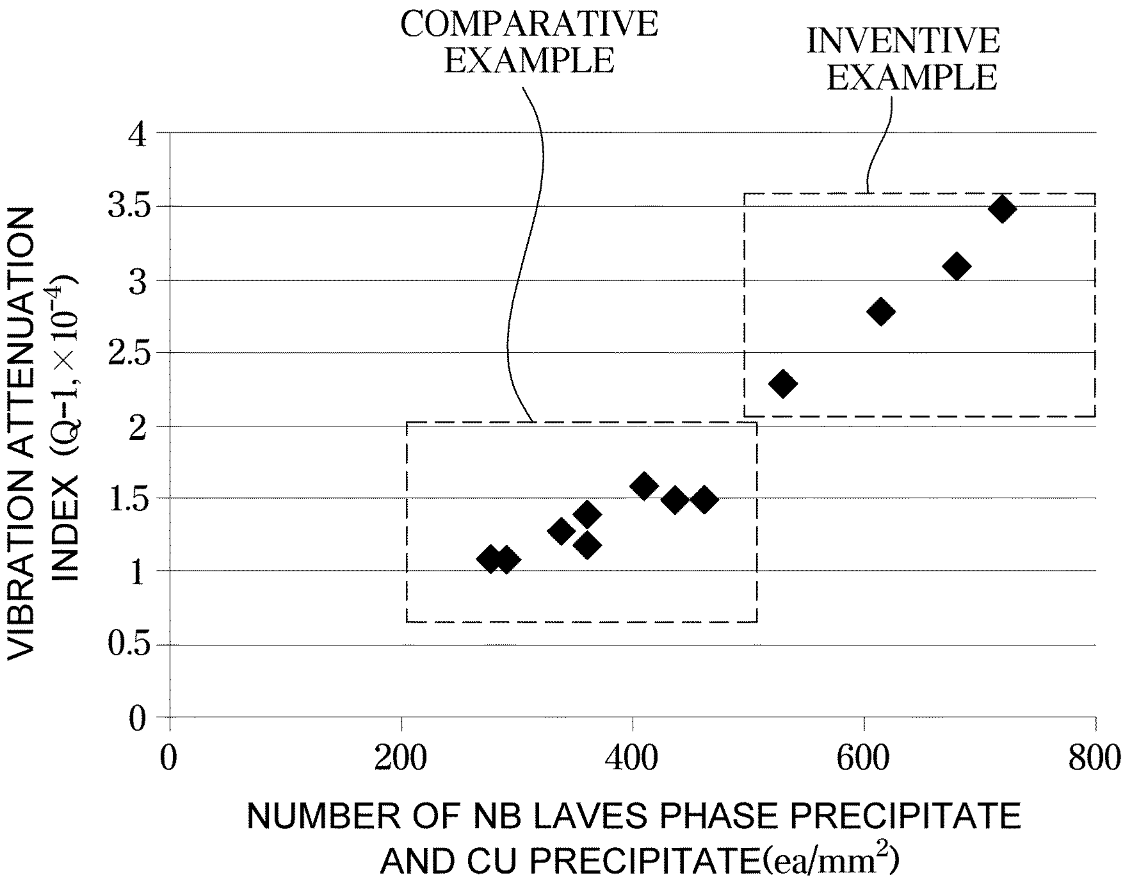
   (Nb, Cu, Ti mean the content (% by weight) of each element) [Cla

8. The manufacturing method of claim 6, wherein the cold-rolled steel plate satisfies the following equation (2)

   (2) $Nb+Cu \leq 0.5$

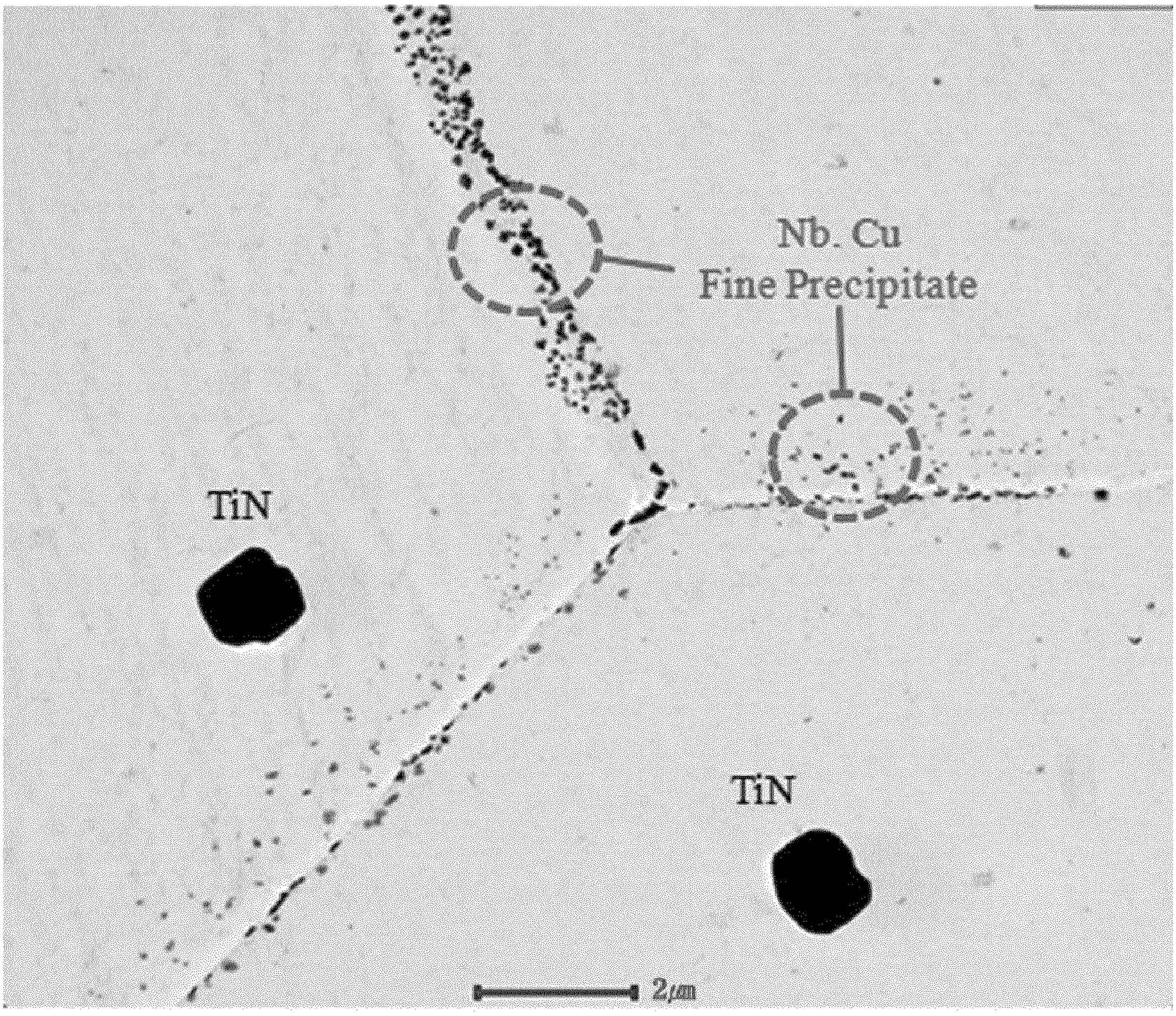
   (Nb, Cu mean the content (% by weight) of each element)

FIG. 1



COMPARATIVE EXAMPLE
INVENTIVE EXAMPLE
VIBRATION ATTENUATION INDEX (Q-1, ×10-4)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
NUMBER OF NB LAVES PHASE PRECIPITATE AND CU PRECIPITATE(ea/mm2)

FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2018/010699

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/50(2006.01)i, C22C 38/48(2006.01)i, C22C 38/42(2006.01)i, C22C 38/06(2006.01)i, C22C 38/04(2006.01)i, C22C 38/02(2006.01)i, C22C 38/00(2006.01)i, C21D 6/00(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 38/50; B21B 37/74; C21D 6/00; C22C 38/00; C22C 38/28; C22C 38/38; C22C 38/48; C22C 38/42; C22C 38/06; C22C 38/04; C22C 38/02

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: stainless steel, ferrite, chrome, laves, niobium, copper, precipitate, cooling, cold rolling

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2009-299182 A (NISSHIN STEEL CO., LTD.) 24 December 2009 See paragraphs [0014], [0019], [0031], [0036], [0039] and claims 1, 3-5, 11.	1-5 6-8
A	CN 102234740 A (BAOSHAN IRON & STEEL CO., LTD.) 09 November 2011 See paragraphs [0050], [0051] and claims 1, 6.	1-8
A	KR 10-1762046 B1 (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORPORATION) 26 July 2017 See paragraph [0119] and claims 1, 5.	1-8
A	JP 2010-070799 A (JFE STEEL CORP.) 02 April 2010 See paragraphs [0088], [0089] and claims 1, 2, 4, 7.	1-8
A	KOBAYASHI et al. Effect of Nb Addition on Cu Precipitation in Ferritic Stainless Steel. ISIJ international. vol. 51, no. 4, 2011, pp. 657-662 See pages 657, 658.	1-8

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

* Special categories of cited documents:
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"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
"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
"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
22 MARCH 2019 (22.03.2019)	**22 MARCH 2019 (22.03.2019)**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2018/010699

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