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(54) **FERRITIC STAINLESS STEEL HAVING IMPROVED MAGNETIC PROPERTIES AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed herein are ferritic stainless steel and a manufacturing method wherein the ferritic stainless steel has magnetic properties improved by controlling alloy components and a manufacturing process in order to increase responsiveness to an externally applied magnetic field. The ferritic stainless steel having improved magnetic properties according to an embodiment of the

present invention may comprise, by % by weight, C: 0% (exclusive) to 0.02% (inclusive), N: 0% (exclusive) to 0.02% (inclusive), Si: 0.5% to 2.0% (both inclusive), Mn: 0.1% to 0.3% (both inclusive), Cr: 16.0% to 20.1% (both inclusive), Mo: 1.0% (exclusive) to 2.0% (inclusive), Ti: 0.1% to 0.4% (both inclusive), and the balance of iron (Fe) and inevitable impurities.

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**Description**

[Technical Field]

5 **[0001]** The disclosure relates to a ferritic stainless steel having magnetic properties enhanced by controlling alloy compositions and manufacturing processes and a method thereof to increase responsiveness to externally applied magnetic fields.

[Background Art]

10 **[0002]** With the recent development in technical areas such as smartphones, semi-autonomous driving vehicles, etc., various electronic devices are being used, which leads to a rapid increase in the use of electromagnetic waves. This causes an increase in interference by electromagnetic waves between electronic devices. The interference by electromagnetic waves may cause malfunction of the device or make it difficult for the device to be precisely controlled. To  
15 prevent malfunction of the electronic device caused by interference by electromagnetic waves, critical devices need to be covered by a material that may shield magnetic fields.

**[0003]** In a case of low frequency or magnetic field shielding, a material having high magnetic permeability has good shielding capability, and especially, there is a growing demand for a material that exhibits high magnetic permeability for a low externally applied magnetic field.

20 **[0004]** Research has thus far been conducted about a material that exhibits high permeability for high externally applied magnetic fields, but it has a problem having deteriorated responsiveness to the externally applied magnetic field.

[Disclosure]

[Technical Problem]

**[0005]** To solve the above problem, an objective of the disclosure is to provide a ferritic stainless steel having enhanced magnetic properties that exhibit high magnetic permeability for low externally applied magnetic fields to increase re-  
sponsiveness to electromagnetic wave shielding, and a method of manufacturing the ferritic stainless steel.

[Technical Solution]

**[0006]** According to an embodiment of the disclosure, a ferritic stainless steel having enhanced magnetic properties comprises, in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other  
35 unavoidable impurities, wherein the value of formula (1) below is 130 or less:

$$40 \quad \text{formula (1): } 30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo]$$

**[0007]** In formula (1), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

**[0008]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may satisfy the value of formula (2) below being 50 or less:

$$45 \quad \text{formula (2): } 18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$$

50 **[0009]** In formula (2), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

**[0010]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may further comprise, in percent by weight (wt%), more than 0 to 0.1% of Nb and more than 0 to 0.1% of Sn.

**[0011]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have a maximum magnetic permeability of 1,000 or more in a 50 Hz frequency band.

55 **[0012]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have an externally applied magnetic field of 130 A/m to exhibit a maximum magnetic permeability.

**[0013]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have a coercivity of less than 50 Alm on condition of exhibiting a maximum magnetic permeability in a 50 Hz frequency band.

**[0014]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have a pitting potential value of 300 mV or more.

**[0015]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have a hardness of 140 Hv or more.

**[0016]** According to an embodiment of the disclosure, a method of manufacturing a ferritic stainless steel having enhanced magnetic properties comprises manufacturing a slab comprising, in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other unavoidable impurities, wherein the value of formula (1) below is 130 or less and the value of formula (2) below is 50 or less; manufacturing a hot-rolled material by hot rolling the slab at a reheating temperature of 1050 to 1150 °C; manufacturing a cold-rolled material by cold rolling the hot-rolled material; and finally annealing the cold-rolled material at 1050 to 1150 °C.

$$30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo] \quad \text{formula(1):}$$

**[0017]** In formula (1), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

$$\text{formula (2): } 18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$$

**[0018]** In formula (2), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

**[0019]** In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel having enhanced magnetic properties, the cold rolling may be performed at a reduction rate of 70% or more.

[Advantageous Effects]

**[0020]** According to an embodiment of the disclosure, a ferritic stainless steel having enhanced magnetic properties that exhibit high magnetic permeability for low externally applied magnetic fields to increase responsiveness to electro-magnetic wave shielding by deriving a component system indicating high permeability, and a method of manufacturing the ferritic stainless steel may be provided.

[Best Mode]

**[0021]** According to an embodiment of the disclosure, a ferritic stainless steel having enhanced magnetic properties comprises, in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other unavoidable impurities, wherein the value of formula (1) below is 130 or less:

$$30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo] \quad \text{formula (1):}$$

**[0022]** In formula (1), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

[Modes]

**[0023]** Reference will now be made in detail to embodiments, which are illustrated in the accompanying drawings. The following embodiments are provided as examples to convey the full spirit of the disclosure to those of ordinary skill in the art to which the embodiments of the disclosure belong. The disclosure is not limited to the embodiments but may be specified in any other forms. Throughout the specification, the term "include (or including)" or "comprise (or comprising)" is inclusive or open-ended and does not exclude additional, unrecited components, elements or method steps, unless otherwise stated.

**[0024]** It is to be understood that the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise.

**[0025]** In an embodiment of the disclosure, a ferritic stainless steel having enhanced magnetic properties may comprise, in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other unavoidable impurities.

**[0026]** A reason for numerical limitation of the content of an alloy composition in an embodiment of the disclosure will

now be described. A unit of wt% will now be used unless otherwise mentioned.

**[0027]** The content of C (carbon) may be more than 0 to 0.02%.

**[0028]** C is an impurity element that is unavoidably contained in a steel, so it is desirable to reduce the content as much as possible. When there is an excessive content of C, magnetic properties deteriorate due to the formation of carbide, and thus magnetic permeability may be deteriorated. Furthermore, when the content of C is excessive, an elongation rate decreases due to the increase in impurities, a value of work hardening coefficient  $n$  decreases, and ductile to brittle transition temperature (DBTT) increases, leading to a decrease in impact characteristics. Considering this, an upper limit of the content of C is limited to 0.02%. In consideration of machinability and mechanical characteristics, the upper limit of the content of C may be desirably limited to 0.01 wt%.

**[0029]** The content of N (nitrogen) may be more than 0% to 0.02%.

**[0030]** When the content of N is excessive, an elongation rate decreases due to the increase in impurities of the material, and ductile to brittle transition temperature (DBTT) increases, leading to a decrease in impact characteristics. Furthermore, when the content of N is excessive, rod-shaped AlN precipitates are formed, causing grain refinement, resulting in deterioration of iron loss. Considering this, the upper limit of the content of N may be limited to 0.02%. In consideration of machinability and mechanical characteristics, the upper limit of the content of N may be desirably limited to 0.015 wt%.

**[0031]** The content of Si (silicon) may be 0.5% to 2.0%.

**[0032]** Si is an effective element for making an increase in magnetic permeability for a low externally applied magnetic field. Considering this, 0.5% or more of Si may be added. However, the content of Si is excessive, the elongation rate decreases, a value of the work hardening coefficient  $n$  decreases, and Si-based inclusions increase, leading to deterioration of machinability. Considering this, the upper limit of the content of Si may be limited to 2.0%. In consideration of machinability, the upper limit of the content of Si may be desirably limited to 1.0 wt%.

**[0033]** The content of Mn (manganese) may be 0.1 to 0.3%.

**[0034]** When the content of Mn is low, fine MnS precipitates are formed, causing grain refinement and thus weakening the magnetic properties. Hence, 0.1% or more of Mn may be added so that MnS precipitates may be formed coarsely. However, when the content of Mn is excessive, the magnetic properties may deteriorate due to an increase in the MnS precipitate fraction. Considering this, the upper limit of the content of Mn may be limited to 0.3%.

**[0035]** The content of Cr (chrome) may be 16.0 to 20.1%.

**[0036]** Cr is an element that improves corrosion resistance by forming a passive film in an oxidizing environment. Considering this, 16.0% or more of Cr may be added. However, when the content of Cr is excessive, it promotes delta ( $\delta$ ) ferrite formation in the slab, reducing the elongation rate and impact toughness, and reduces magnetic permeability. Considering this, the upper limit of the content of Cr may be limited to 20.1%.

**[0037]** The content of Mo (molybdenum) may be more than 1.0 to 2.0%.

**[0038]** Mo is an effective element to increase the corrosion resistance of stainless steel. Considering this, 1.0% or more may be added. However, when the content of Mo is excessive, it is segregated on grain boundaries and plays a role in suppressing grain growth, causing grain refinement and thus deteriorating magnetic properties. Considering this, the upper limit of the content of Mo may be limited to 2.0%.

**[0039]** The content of Ti (titanium) may be 0.1 to 0.4%.

**[0040]** Ti is an effective element to enhance strength by causing precipitation. Considering this, 0.1% or more of Ti may be added. However, when the Ti content is excessive, Ti-based precipitates increase excessively, which prohibits the grain size from increasing sufficiently, causing a problem of lowering permeability. Considering this, the upper limit of the content of Ti may be limited to 0.4%.

**[0041]** The remaining component is iron (Fe) in the disclosure. However, unintended impurities may be inevitably mixed from raw materials or surroundings in the normal manufacturing process, so they may not be excluded. These impurities may be known to anyone skilled in the ordinary manufacturing process, so not all of them are specifically mentioned in this specification.

**[0042]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may further comprise, in percent by weight (wt%), more than 0 to 0.1% of Nb and more than 0 to 0.1% of Sn.

**[0043]** The content of Nb (niobium) may be more than 0 to 0.1%.

**[0044]** Like Ti, Nb is an element that forms a fine precipitate phase. However, while Ti forms a relatively high temperature phase, thereby preventing fine precipitation by heat treatment, Nb forms a stable phase at a relatively low temperature, so it is re-dissolved during hot rolling and may cause fine precipitation during annealing. Hence, when the content of Nb is excessive, magnetic properties may deteriorate due to the fine precipitation, so it is desirable to manage it as an impurity. Considering this, the upper limit of the content of Nb may be limited to 0.1%.

**[0045]** The content of Sn (tin) may be more than 0 to 0.1%.

**[0046]** Like Ti, Sn is an element that forms a fine precipitate phase. However, while Ti forms a relatively high temperature phase, thereby preventing fine precipitation by heat treatment, Sn forms a stable phase at a relatively low temperature, so it is re-dissolved during hot rolling and fine precipitation may be caused during annealing. Hence, when the content

of Sn is excessive, magnetic properties may deteriorate due to the fine precipitation, so it is desirable to manage it as an impurity. Considering this, the upper limit of the content of Sn may be limited to 0.1%.

**[0047]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties satisfies the value of the following formula (1) being 130 or less.

$$30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo] \quad \text{formula (1):}$$

**[0048]** In formula (1), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

**[0049]** The disclosure provides a ferritic stainless steel having enhanced magnetic properties that exhibit high magnetic permeability for low externally applied magnetic field to increase responsiveness to electromagnetic wave shielding, and a method of manufacturing the ferritic stainless steel. In a case that the value of formula (1) exceeds 130, it exhibits a large magnetic permeability value for a relatively high externally applied magnetic field, so the responsiveness to electromagnetic wave shielding deteriorates. Hence, the value of formula (1) may be 130 or less.

**[0050]** By controlling the value of formula (1) to be 130 or less, the ferritic stainless steel having enhanced magnetic properties according to an embodiment of the disclosure may have a maximum magnetic permeability of 1,000 or more in a 50 Hz frequency band. Furthermore, an externally applied magnetic field to exhibit maximum magnetic permeability may be 130 A/m or less.

**[0051]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties satisfies the value of the following formula (2) being 50 or less.

$$\text{formula (2): } 18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$$

**[0052]** In formula (2), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

**[0053]** Coercivity refers to the magnitude of an external magnetic field in a reverse direction required to restore a magnetized magnetic substance into a demagnetized state. When the value of formula (2) exceeds 50, coercivity increases so the shielding capability may be deteriorated. Hence, the value of formula (2) may be 50 or less.

**[0054]** By controlling formula (2) to be 50 or less, the ferritic stainless steel having enhanced magnetic properties may have a coercivity of less than 50 Alm on condition of exhibiting the maximum magnetic permeability in the 50 Hz frequency band.

**[0055]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have a pitting potential value of 300 mV or more by controlling alloy compositions and manufacturing processes to enhance corrosion resistance.

**[0056]** In an embodiment of the disclosure, the ferritic stainless steel having enhanced magnetic properties may have a hardness of 140 Hv or more by controlling alloy compositions and manufacturing processes to enhance strength.

**[0057]** A method of manufacturing a ferritic stainless steel having enhanced magnetic properties according to another aspect of the disclosure will now be described.

**[0058]** According to an embodiment of the disclosure, a method of manufacturing a ferritic stainless steel having enhanced magnetic properties comprises manufacturing a slab comprising, in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other unavoidable impurities, wherein the value of equation (1) below is 130 or less and the value of equation (2) below is 50 or less; manufacturing a hot-rolled material by hot rolling the slab at a reheating temperature of 1050 to 1150 °C; manufacturing a cold-rolled material by cold rolling the hot-rolled material; and finally annealing the cold-rolled material at 1050 to 1150 °C.

$$30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo] \quad \text{Formula (1):}$$

**[0059]** In formula (1), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

$$\text{formula (2): } 18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$$

**[0060]** In formula (2), [C], [N], [Si], [Cr], and [Mo] each refer to a content (wt%) of the element.

**[0061]** The reason of numerical limitations of component ranges and component relation formula of each alloy composition is the same as described above, and each manufacturing step will now be described in more detail.

**[0062]** First, after the slab that satisfies the alloy composition and component relation formula is manufactured, it goes through a series of processes of hot rolling, cold rolling and final annealing.

**[0063]** The slab may be hot-rolled at a reheating temperature of 1050 to 1150 °C.

**[0064]** When the reheating temperature of the slab is too low, the load of the rolling roll may increase, the coarse precipitates created during slab casting has difficulty in being re-decomposed, and the internal structure may have difficulty in being homogenized. Considering this, the reheating temperature of the slab may be 1050 °C or more. However, when the reheating temperature is too high, the grain diameter of the slab may be excessively coarse, which may deteriorate the strength. Considering this, the upper limit of the reheating temperature of the slab may be limited to 1150 °C.

**[0065]** The cold rolling may be performed at a reduction rate of 70% or more. When the reduction rate is less than 70%, it may be difficult to attain the desired strength.

**[0066]** The cold-rolled material may be finally annealed at 1050 to 1150 °C.

**[0067]** When the final annealing temperature is low, it requires a long time, thereby increasing manufacturing costs. Considering this, the final annealing temperature may be 1050 °C or more. However, when the final annealing temperature is high, the microstructure may be excessively coarse, resulting in deterioration of the mechanical properties. Considering this, the final annealing temperature may be 1150 °C or less.

**[0068]** Embodiments of the disclosure will now be described in more detail. The embodiments may be merely for illustration, and the disclosure is not limited thereto. The scope of the disclosure is defined by the claims and their equivalents.

{Embodiments}

**[0069]** A steel having various chemical compositions shown in Table 1 below were cast into a slab, and the cast slab were reheated at 1050 °C. A final cold-rolled product was manufactured by hot rolling the reheated slab, performing cold rolling at a reduction rate of 70% and performing final annealing at a temperature of 1050 °C.

[Table 1]

|                       | C            | N     | Si          | Mn          | Cr          | Mo         | Ti          |
|-----------------------|--------------|-------|-------------|-------------|-------------|------------|-------------|
| Example 1             | 0.005        | 0.007 | 0.50        | 0.18        | 17.8        | 1.1        | 0.34        |
| Example 2             | 0.006        | 0.007 | 0.99        | 0.20        | 17.8        | 1.1        | 0.32        |
| Example 3             | 0.018        | 0.006 | 2.00        | 0.20        | 17.0        | 1.1        | 0.31        |
| Example 4             | 0.006        | 0.006 | 1.92        | 0.20        | 17.7        | 1.1        | 0.12        |
| Example 5             | 0.005        | 0.007 | 1.03        | 0.19        | 20.1        | 1.1        | 0.29        |
| Example 6             | 0.005        | 0.008 | 0.98        | 0.20        | 20.0        | 1.1        | 0.29        |
| Example 7             | 0.005        | 0.007 | 1.03        | 0.20        | 17.8        | 1.7        | 0.29        |
| Comparative example 1 | 0.006        | 0.008 | <b>0.12</b> | 0.20        | 17.7        | 1.1        | 0.25        |
| Comparative example 2 | 0.006        | 0.007 | <b>0.30</b> | 0.21        | 18.3        | 1.8        | <b>0.08</b> |
| Comparative example 3 | 0.005        | 0.008 | 0.85        | 0.20        | 17.7        | 1.8        | 0.28        |
| Comparative example 4 | <b>0.039</b> | 0.017 | <b>0.39</b> | <b>0.33</b> | 17.1        | <b>0.0</b> | <b>0.00</b> |
| Comparative example 5 | 0.011        | 0.018 | <b>0.34</b> | 0.21        | <b>21.0</b> | <b>0.0</b> | <b>0.00</b> |

**[0070]** Values of formula (1) and formula (2), maximum magnetic permeability, applied magnetic fields, coercivity and hardness were shown in Table 2 below. The value of formula (1) is one calculated by  $30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo]$ .

**[0071]** In formula (1), [C], [N], [Si], [Cr] and [Mo] each refer to a content (wt%) of the element.

**[0072]** The value of formula (2) is one calculated by  $18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$ .

**[0073]** In formula (2), [C], [N], [Si], [Cr] and [Mo] each refer to a content (wt%) of the element.

**[0074]** For the final cold-rolled product, the magnetic properties were evaluated by measuring a magnetic field from magnetization of the material while gradually increasing the externally applied magnetic field in a frequency band of 50 Hz.

**[0075]** The maximum magnetic permeability was measured by touching a probe onto a cross-section of a steel sample with a diameter of 20 mm or more and a thickness of 5 mm or more using a non-magnetic permeability meter whose model name is Ferropro FP-5.

**[0076]** The pitting potential indicated a value obtained by applying potential in an immersed solution of NaCl and

measuring a potential at which pitting is generated. The NaCl solution has a temperature of 30 °C and a concentration of 3.5%.

**[0077]** The hardness was measured using a Vickers hardness meter from Zwick Roell.

[Table 2]

|                        | formula<br>(1) | formula<br>(2) | maximu m<br>magnetic<br>permeabi lity | applied<br>magnetic<br>field (A/m) | coercivit<br>y (A/m) | pitting<br>potential<br>(mV) | Hardness<br>(Hv) |
|------------------------|----------------|----------------|---------------------------------------|------------------------------------|----------------------|------------------------------|------------------|
| Examl e 1              | 121.2          | 49             | 1737                                  | 122                                | 48                   | 362                          | 146              |
| Examl e 2              | 116.4          | 46.9           | 1386                                  | 120                                | 45                   | 365                          | 163              |
| Examl e 3              | 126.7          | 48.8           | 2020                                  | 128                                | 47                   | 483                          | 193              |
| Examl e 4              | 99.7           | 40.4           | 1901                                  | 100                                | 40                   | 459                          | 190              |
| Examl e 5              | 119            | 48.1           | 2008                                  | 120                                | 47                   | 499                          | 168              |
| Examl e 6              | 122            | 49.1           | 1921                                  | 120                                | 48                   | 482                          | 166              |
| Examl e 7              | 126.5          | 49.4           | 1571                                  | 129                                | 49                   | 462                          | 171              |
| Compar ative example 1 | 131.7          | 52.8           | 1653                                  | 133                                | 52                   | 317                          | 140              |
| Compar ative example 2 | 143.4          | 55.7           | 1493                                  | 160                                | 65                   | 461                          | 165              |
| Compar ative example 3 | 133.6          | 51.8           | 1419                                  | 132                                | 50                   | 450                          | 169              |
| Compar ative example 4 | 206.9          | 77.6           | 1589                                  | 200                                | 88                   | 278                          | 162              |
| Compar ative example 5 | 149.9          | 60.2           | 1738                                  | 183                                | 87                   | 362                          | 160              |

**[0078]** Referring to table 2, Examples 1 to 7 all satisfied the value of formula (1) being 130 or less and the value of formula (2) being 50 or less. Hence, it was satisfied that in a 50 Hz frequency band, the maximum magnetic permeability was 1,000 or more, the externally applied magnetic field to exhibit the maximum magnetic permeability was 130 A/m or less, and the coercivity was 50 A/m or less on condition of exhibiting the maximum magnetic permeability. In other words, Examples 1 to 7 showed a high magnetic permeability for a low externally applied magnetic field, so it is understood that responsiveness to electromagnetic wave shielding increased and magnetic properties were enhanced. Furthermore, Examples 1 to 7 satisfied the pitting potential value being 300 mV or more and the hardness being 140 Hv. In other words, Examples 1 to 7 had good corrosion resistance and hardness.

**[0079]** Comparative examples 1 to 5 did not satisfy the value of formula (1) being 130 or less. Hence, comparative examples 1 to 5 did not satisfy the externally applied magnetic field being 130 A/m to exhibit a maximum magnetic permeability. Furthermore, comparative examples 1 to 5 did not satisfy the value of formula (2) being 50 or less. Hence, comparative examples 1 to 5 did not satisfy the coercivity being 50 A/m or less. In other words, comparative examples 1 to 5 have a relatively high externally applied magnetic field, so it is understood that responsiveness to electromagnetic wave shielding was deteriorated.

**[0080]** Furthermore, comparative example 4 did not add the Mo element and did not satisfy a pitting potential value being 300 mV or more due to a relatively low amount of content of Cr. In other words, comparative example 4 had deteriorated corrosion resistance.

[Industrial Applicability]

**[0081]** According to an embodiment of the disclosure, a ferritic stainless steel having enhanced magnetic properties that exhibit high magnetic permeability for low externally applied magnetic field to increase responsiveness to electromagnetic wave shielding by deriving a component system indicating high permeability, and a method of manufacturing the ferritic stainless steel are provided, so the industrial applicability is acknowledged.

## Claims

1. A ferritic stainless steel having enhanced magnetic properties comprising:

in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other unavoidable impurities,  
wherein a value of the following formula (1) is 130 or less:

$$\text{formula (1): } 30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo]$$

(in formula (1), [C], [N], [Si], [Cr] and [Mo] each refer to a content (wt%) of the element).

2. The ferritic stainless steel having enhanced magnetic properties of claim 1, wherein a value of the following formula (2) is 50 or less:

$$\text{Formula (2): } 18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$$

(in formula (2), [C], [N], [Si], [Cr] and [Mo] each refer to a content (wt%) of the element).

3. The ferritic stainless steel having enhanced magnetic properties of claim 1, further comprising, in percent by weight (wt%), more than 0 to 0.1% of Nb and more than 0% to 0.1% of Sn.
4. The ferritic stainless steel having enhanced magnetic properties of claim 1, wherein a maximum magnetic permeability in the 50 Hz frequency band is 1,000 or more.
5. The ferritic stainless steel having enhanced magnetic properties of claim 1, wherein an externally applied magnetic field is 130 A/m or less to exhibit a maximum magnetic permeability.
6. The ferritic stainless steel having enhanced magnetic properties of claim 1, wherein coercivity is less than 50 Alm on condition of exhibiting a maximum magnetic permeability in a 50 Hz frequency band.
7. The ferritic stainless steel having enhanced magnetic properties of claim 1, wherein a pitting potential value is 300 mV or more.
8. The ferritic stainless steel having enhanced magnetic properties of claim 1, wherein hardness is 140 Hv or more.
9. A method of manufacturing a ferritic stainless steel having enhanced magnetic properties, the method comprising:

manufacturing a slab comprising, in percent by weight (wt%), more than 0 to 0.02% of C, more than 0 to 0.02% of N, 0.5 to 2.0% of Si, 0.1 to 0.3% of Mn, 16.0 to 20.1% of Cr, more than 1.0 to 2.0% of Mo, 0.1 to 0.4% of Ti, and the remainder having Fe and other unavoidable impurities, wherein a value of formula (1) below is 130 or less and a value of following formula (2) below is 50 or less;  
manufacturing a hot-rolled material by hot-rolling the slab at a reheating temperature of 1050 to 1150 °C;  
manufacturing a cold-rolled material by cold-rolling the hot-rolled material; and  
finally annealing the cold-rolled material at 1050 to 1150 °C:

$$\text{formula (1): } 30 + 2500 * ([C] + [N]) - 15 * [Si] + 2.5 * [Cr] + 22 * [Mo]$$

(in formula (1), [C], [N], [Si], [Cr] and [Mo] each refer to a content (wt%) of the element)

$$\text{formula (2): } 18 + 800 * ([C] + [N]) - 6 * [Si] + [Cr] + 6 * [Mo]$$

(in formula (2), [C], [N], [Si], [Cr] and [Mo] each refer to a content (wt%) of the element).

10. The method of manufacturing a ferritic stainless steel having enhanced magnetic properties of claim 9, wherein the cold-rolling is performed at a reduction rate of 70% or more.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/015945

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><b>C22C 38/34(2006.01)i; C22C 38/22(2006.01)i; C22C 38/28(2006.01)i; C22C 38/26(2006.01)i; C22C 38/00(2006.01)i; C21D 8/02(2006.01)i</b><br><br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
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| <b>B. FIELDS SEARCHED</b><br><br>Minimum documentation searched (classification system followed by classification symbols)<br>C22C 38/34(2006.01); C21D 8/12(2006.01); C22C 38/00(2006.01); C22C 38/18(2006.01); C22C 38/32(2006.01); C22C 38/50(2006.01); C22C 38/58(2006.01); C22C 38/60(2006.01)<br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Korean utility models and applications for utility models: IPC as above<br>Japanese utility models and applications for utility models: IPC as above<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>eKOMPASS (KIPO internal) & keywords: 페라이트계 스테인리스강(ferritic stainless steel), 자기적 성질(magnetic property), 망간(Mn), 크롬(Cr), 몰리브덴(Mo), 티타늄(Ti)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>Y</td> <td>JP 2020-063472 A (NIPPON STEEL STAINLESS STEEL CORP.) 23 April 2020 (2020-04-23)<br/>See paragraphs [0029], [0039], [0041]-[0042] and [0055] and claims 1-2.</td> <td>1-10</td> </tr> <tr> <td>Y</td> <td>JP 2021-161469 A (NIPPON STEEL STAINLESS STEEL CORP.) 11 October 2021 (2021-10-11)<br/>See paragraphs [0034] and [0056] and claims 1-2.</td> <td>1-10</td> </tr> <tr> <td>Y</td> <td>JP 09-176802 A (NIPPON STEEL CORP.) 08 July 1997 (1997-07-08)<br/>See paragraph [0015] and claim 6.</td> <td>9-10</td> </tr> <tr> <td>A</td> <td>JP 2013-185183 A (NIPPON STEEL &amp; SUMIKIN STAINLESS STEEL CORP. et al.) 19 September 2013 (2013-09-19)<br/>See claims 1-2 and 6.</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>KR 10-2006-0049716 A (NIPPON STEEL &amp; SUMIKIN STAINLESS STEEL CORPORATION) 19 May 2006 (2006-05-19)<br/>See claims 1, 3 and 7.</td> <td>1-10</td> </tr> </tbody> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Relevant to claim No. | Y | JP 2020-063472 A (NIPPON STEEL STAINLESS STEEL CORP.) 23 April 2020 (2020-04-23)<br>See paragraphs [0029], [0039], [0041]-[0042] and [0055] and claims 1-2. | 1-10 | Y | JP 2021-161469 A (NIPPON STEEL STAINLESS STEEL CORP.) 11 October 2021 (2021-10-11)<br>See paragraphs [0034] and [0056] and claims 1-2. | 1-10 | Y | JP 09-176802 A (NIPPON STEEL CORP.) 08 July 1997 (1997-07-08)<br>See paragraph [0015] and claim 6. | 9-10 | A | JP 2013-185183 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORP. et al.) 19 September 2013 (2013-09-19)<br>See claims 1-2 and 6. | 1-10 | A | KR 10-2006-0049716 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORPORATION) 19 May 2006 (2006-05-19)<br>See claims 1, 3 and 7. | 1-10 |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Relevant to claim No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
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| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
| <table border="0"> <tr> <td style="vertical-align: top;">           * Special categories of cited documents:<br/>           "A" document defining the general state of the art which is not considered to be of particular relevance<br/>           "D" document cited by the applicant in the international application<br/>           "E" earlier application or patent but published on or after the international filing date<br/>           "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)<br/>           "O" document referring to an oral disclosure, use, exhibition or other means<br/>           "P" document published prior to the international filing date but later than the priority date claimed         </td> <td style="vertical-align: top;">           "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<br/>           "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<br/>           "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<br/>           "&amp;" document member of the same patent family         </td> </tr> </table> | * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"D" document cited by the applicant in the international application<br>"E" earlier application or patent but published on or after the international filing date<br>"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)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"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<br>"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<br>"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<br>"&" document member of the same patent family |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"D" document cited by the applicant in the international application<br>"E" earlier application or patent but published on or after the international filing date<br>"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)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"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<br>"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<br>"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<br>"&" document member of the same patent family       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
| <table border="1"> <tr> <td>Date of the actual completion of the international search<br/><b>30 January 2023</b></td> <td>Date of mailing of the international search report<br/><b>31 January 2023</b></td> </tr> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Date of the actual completion of the international search<br><b>30 January 2023</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Date of mailing of the international search report<br><b>31 January 2023</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
| Date of the actual completion of the international search<br><b>30 January 2023</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Date of mailing of the international search report<br><b>31 January 2023</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
| <table border="1"> <tr> <td>           Name and mailing address of the ISA/KR<br/> <b>Korean Intellectual Property Office<br/>           Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208</b><br/>           Facsimile No. +82-42-481-8578         </td> <td>           Authorized officer<br/><br/><br/>           Telephone No.         </td> </tr> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Name and mailing address of the ISA/KR<br><b>Korean Intellectual Property Office<br/>           Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208</b><br>Facsimile No. +82-42-481-8578                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Authorized officer<br><br><br>Telephone No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                       |   |                                                                                                                                                             |      |   |                                                                                                                                        |      |   |                                                                                                    |      |   |                                                                                                                                |      |   |                                                                                                                              |      |
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INTERNATIONAL SEARCH REPORT

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| C. DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                           |                       |
|----------------------------------------|-------------------------------------------------------------------------------------------|-----------------------|
| Category*                              | Citation of document, with indication, where appropriate, of the relevant passages        | Relevant to claim No. |
| A                                      | CN 101492792 A (BAOSHAN IRON & STEEL CO., LTD.) 29 July 2009 (2009-07-29)<br>See claim 1. | 1-10                  |

**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/KR2022/015945**

| Patent document<br>cited in search report | Publication date<br>(day/month/year) | Patent family member(s) | Publication date<br>(day/month/year) |
|-------------------------------------------|--------------------------------------|-------------------------|--------------------------------------|
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| JP 2021-161469 A                          | 11 October 2021                      | None                    |                                      |
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