LOW CHROME FERRITIC STAINLESS STEEL WITH HIGH CORROSION RESISTANCE AND STRETCHABILITY AND METHOD OF MANUFACTURING THE SAME

Abstract: The present invention relates to a low chrome ferritic stainless steel with a high corrosion resistance and stretchability and a method of manufacturing the same, wherein the low chrome ferritic stainless steel with the high corrosion resistance and stretchability is composed of C of 0.03wt% or less, Si of 0.5wt% or less, Mn of 0.5wt% or less, P of 0.035wt% or less, S of 0.01wt% or less, Cr of 14 to 16wt%, Mo of 0.2wt% or less, N of 0.030wt% or less, Cu of 0.5wt% or less, Al of 0.05wt% or less, Ni of 0.2wt% or less, C+N of 0.040wt% or less, Ti of 0.5wt% or less, remaining Fe and, inevitably added impurities, being controlled in EL value defined by Equation 1 below to be 33 or more and in P.I. value defined by Equation 2 below to be in a range of 14 to 16.

\[ EL = -162.1x(C+N) - 0.2xCr - 1.1xMo - 0.2xTi/(C+N) + 42.2 \]  
\[ P.I. = Cr + 3.3Mo \]
Description

LOW CHROME FERRITIC STAINLESS STEEL WITH HIGH CORROSION RESISTANCE AND STRETCHABILITY AND METHOD OF MANUFACTURING THE SAME

Technical Field

[1] The present invention relates to a low chrome ferritic stainless steel with a high corrosion resistance and stretchability and a method of manufacturing the same, and more specifically to a low chrome ferritic stainless steel with a high corrosion resistance and stretchability and a method of manufacturing the same used in various pipes and a muffler of a cold zone of an automobile exhaust system requiring a high corrosion resistance and a high formability.

Background Art

[2] Generally, in a ferritic stainless steel, Cr and Mo are added in order to improve corrosion resistance. However, when expensive Cr and Mo are added, fabrication cost is raised, and elongation reduces so that stretchability is deteriorated at forming a muffler of a stamping type, etc, thereby causing fracture of the stainless steel. Also, when temperature is low as in winter, fracture frequently occurs in a case of expanding a pipe after TIG welding like an exhaust system end pipe, etc.

[3] In order to solve these problems, several conventional techniques have been known. In Europe Patent No. 0930375, a manufacturing method improving dip drawability and ridging properties by combining a component composition and a hot rolling condition has been disclosed. In Japan Patent Laid-Open Publication No. 2000-328197, a method improving surface gloss and formability by adding a proper amount of Al has been disclosed. Also, in Europe Patent No. 0765741, a method improving ridging resistance and plane anisotropy by optimizing composition, a rolling condition, and an annealing condition has been disclosed. In Japan Patent Laid-Open Publication No. 1995-032997, component composition reference and a manufacturing condition of a cheap ferritic stainless steel with a high corrosion resistance in atmospheric environment have been suggested; however, the content of Cr was defined in a range of 17 to 32% higher than that of the present patent.

[4] However, the above patents do not define component and manufacturing conditions for satisfying both the corrosion resistance and the formability and at the same time, satisfying requirements of a client desiring a low cost. Accordingly, in the case where the ferritic stainless steel is used in the muffler and for expansion of the pipe requiring a high corrosion resistance and a high formability, it is impossible to satisfy quality of a cold rolled product.
Disclosure of Invention

Technical Problem

It is an object of the present invention to provide a low chrome ferritic stainless steel with a high corrosion resistance and stretchability and a method of manufacturing the same capable of improving Ductile-Brittle Transition Temperature (DBTT) by controlling the addition amounts of Ca, Mg, and Zr, and reducing fabrication cost by reducing the addition amounts of Cr and Mo, which are expensive materials, using an EL equation (Equation 1) and a P.I. equation (Equation 2), which are equations calculating an elongation and a fitting index, in order to control heating temperature, finishing rolling temperature, and hot and cold annealing conditions of a slab. Further, it is another object of the present invention to provide a low chrome ferritic stainless steel with a high corrosion resistance and stretchability and a method of manufacturing the same capable of raising pipe expanding properties of a welded portion of a TIG pipe by optimally controlling the contents of addition alloy elements C, N, Si, Mn, Cr, Mo, and Ti and a content ratio of Ti%/(C% + N%) using an EL equation and a P.I. equation.

Technical Solution

A low chrome ferritic stainless steel with a high corrosion resistance and stretchability according to the present invention is composed of C of 0.03wt% or less, Si of 0.5wt% or less, Mn of 0.5wt% or less, P of 0.035wt% or less, S of 0.01wt% or less, Cr of 14 to 16wt%, Mo of 0.2wt% or less, N of 0.030wt% or less, Cu of 0.5wt% or less, Al of 0.05wt% or less, Ni of 0.2wt% or less, C+N of 0.040wt% or less, Ti of 0.5wt% or less, remaining Fe, and inevitably added impurities, being controlled in EL value defined by Equation 1 below to be 33 or more and a P.I. value defined by Equation 2 below to be in a range of 14 to 16.

\[ \text{EL} = -162.1x(C+N)-0.2x\text{Cr}-1.1x\text{Mo}-0.2x\text{Ti}/(C+N)+42.2 \quad (1) \]

\[ \text{P.I.} = \text{Cr}+3.3\text{Mo} \quad (2) \]

Also, in the present invention, the low chrome ferritic stainless steel with the high corrosion resistance and stretchability can contain at least any one component selected from a group consisting of Ca of 0.005wt% or less, Mg of 0.005wt% or less, and Zr of 0.01wt% or less.

Also, in the present invention, the ratio of Ti/(C+N) preferably is in a range of 15 to 20.

Also, a method of manufacturing a low chrome ferritic stainless steel with a high corrosion resistance and stretchability according to the present invention comprises:
hot rolling a slab of the ferritic stainless steel composed as described above at a heating
temperature of 1230 to 1280°C and a finishing rolling temperature of 740 to 850°C; hot
annealing the slab at 900 to 1000°C; cold annealing the slab at 900 to 1000°C to have a
cold reduction ratio 50% or more; and adjusting the slab to have a particle size of a
range of 6.0 to 7.0 in ASTM crystal particle size number.

Advantageous Effects

As described above, according to the present invention, it is possible to improve the
Ductile-Brittle Transition Temperature (DBTT) by adjusting the addition amounts of
Ca, Mg, and Zr, and to reduce fabrication cost by reducing the addition amounts of Cr
and Mo, which are expensive materials, using the EL equation (Equation 1) and the
P-I. equation (Equation 2), which are equations calculating an elongation and a fitting
index, in order to control the heating temperature, the finishing rolling temperature,
and the hot and cold annealing conditions of the slab. Further, it is also possible to
raise the pipe expanding properties of the welded portion of the TIG pipe by optimally
adjusting the contents of the addition alloy elements C, N, Si, Mn, Cr, Mo, and Ti and
a content ratio of Ti%//(C% + N%) using the EL equation and the P-I. equation. Ac-
cordingly, it is possible to manufacture a cheap low chrome ferritic stainless cold
rolled steel with a high corrosion resistance, elongation, stretchability, and pipe
expanding properties at a low temperature. Therefore, it is possible to secure a material
capable of being used for a muffler and an end part of an automobile exhaust system.

Brief Description of the Drawings

FIG. 1 is a view showing a change of elongation according to a change of ASTM
crystal particle size number after cold annealing in a 15Cr-Ti steel (specimen No. 1).
FIG. 2 is a view showing a change of elongation according to the ratio of Ti/(C+N)
in the 15Cr-Ti steel.
FIG. 3 is a view showing a change of Ductile-Brittle Transition Temperature (DBTT)
according to a change of addition amounts of Ca, Mg, and Zr in the 15Cr-Ti steel.

Best Mode for Carrying Out the Invention

Hereinafter, the present invention will be described with reference to the ac-
companying drawings.

According to the present invention, it is possible to solve a problem that 409L steel,
which is 11% Cr steel used for various pipes for an end part of an automobile exhaust
system and for a muffler of the automobile exhaust system has a bad corrosion
resistance so that when it is used for the muffler of the automobile exhaust system,
corrosion due to condensing water frequently occurs. Also, according to the present invention, it is possible to solve a problem that 430 steel, which is 17.5%Cr steel, has a good corrosion resistance, but fabrication cost is raised due to an increase in Cr content, as well as, formability and pipe expanding properties are poor so that it may not be widely used.

To this end, a low chrome ferritic stainless steel having reduced Cr and Mo contents and at the same time, having a high corrosion resistance, stretchability, and pipe expanding properties at a low temperature is composed of C of 0.03wt% or less, Si of 0.5wt% or less, Mn of 0.5wt% or less, P of 0.035wt% or less, S of 0.01wt% or less, Cr of 14 to 16wt%, Mo of 0.2wt% or less, N of 0.030wt% or less, Cu of 0.5wt% or less, Al of 0.05wt% or less, Ni of 0.4wt% or less, C+N of 0.040wt% or less, Ti of 0.05wt% or less, remaining Fe and inevitably added impurities, on condition that an EL value defined by Equation 1 below is controlled to be 33 or more and a P.I. value defined by Equation2 below is controlled to be in a range of 14 to 16.

\[ \text{EL} = -162.1 \times (C+N) - 0.2 \times \text{Cr} - 1.1 \times \text{Mo} - 0.2 \times \text{Ti}/(C+N) + 42.2 \]  \hspace{1cm} (1)

\[ \text{P.I.} = \text{Cr} + 3.3 \times \text{Mo} \]  \hspace{1cm} (2)

In a method of manufacturing such a ferritic stainless steel, a cheap low chrome ferritic stainless steel containing component composition as described above and at least any one component selected from a group consisting of Ca of 0.005wt% or less, Mg of 0.005wt% or less, and Zr of 0.01wt% or less as other alloy composition and satisfying that the ratio of Ti/(C+N) is in a range of 15 to 20 is prepared. After a slab of such a steel is hot rolled at a heating temperature of 1230 to 1280°C and a finishing rolling temperature of 740 to 850°C, it is hot-annealed at 900 to 1000°C. After it is cold-annealed to make a cold reduction ratio of 50% or more, the particle size of a material is adjusted to be a range of 6.0 to 7.0 in ASTM crystal particle size number.

Hereinafter, a composition range of the present invention and a limitation reason thereof will be described in detail.

C and N, which are Ti(C, N) carbonitride forming elements, exist in an interstitial form. When contents of C and N become high, solid C and N not formed into a Ti(C, N) carbonitride deteriorate the elongation and the stretchability of a material. Accordingly, the content of C is limited to be 0.03% or less, and the content of N also is limited to be 0.03% or less. At the same time, when the content of C+N becomes high, a high content of Ti is added so that steelmaking inclusions increase, thereby causing many surface defects such as scab. Also, a nozzle clogging phenomenon occurs at the time of continuous casting, and the elongation of the material is deteriorated due to the increase in the contents of the solid C and N. Therefore, the content of C+N is limited to be 0.04% or less.

Si is a ferritic phase forming element. When content of Si increases, stability of a
ferritic phase becomes high and oxidation resistance is improved. However, when Si of 0.5% or more is added, steelmaking Si inclusions increase so that the surface defect is easy to occur. Also, Si raises hardness, yield strength, and tensile strength but deteriorates the elongation, it is disadvantageous in formability. Therefore, the content of Si is limited to be 0.5% or less.

When content of Mn becomes high, MnS is eluted to deteriorate fitting corrosion resistance. Therefore, the content of Mn is limited to be 0.5% or less.

Ni is a gamma phase forming element. When content of Ni increases, a gamma phase increases. Thus, when air-cooling a coil after hot rolling it, martensite phase generation is promoted to increase strength and hardness so that the elongation is deteriorated. Therefore, the addition amount of Ni is limited to be 0.2% or less.

P and S form inclusions such as MnS, etc., to deteriorate the corrosion resistance and hot rolling formability. Therefore, contents of them are preferably managed as low as possible: the content of P is limited to be 0.035% or less and the content of S is limited to be 0.01% or less.

When content of Cr becomes low, the corrosion resistance is deteriorated. When it becomes too high, the corrosion resistance is improved, whereas the elongation is low to deteriorate formability. Therefore, the content of Cr is limited to a range of 14 to 16%.

When content of expensive Mo increases, the corrosion resistance is remarkably improved, whereas fabrication cost of the material is raised, and the hardness is raised to decrease the elongation, thereby deteriorating the formability. Therefore, the content of Mo is limited to be 0.2% or less in consideration of the corrosion resistance and the formability.

Al is an element added as a deoxidizer. When a large amount of Al is added, the surface defect occurs. Therefore, content of Al is limited to be 0.05% or less.

Cu is a gamma phase forming element like Ni. When a large amount of Cu is added, the gamma phase increases. Thus, when air-cooling the coil after hot rolling it, the martensite phase generation is promoted to increase strength and hardness so that the elongation is deteriorated. Therefore, content of Cu is limited to be 0.5% or less.

When too much Ti is added, the steelmaking inclusions increase to cause many surface defects such as the scab. Also, a nozzle clogging phenomenon occurs at the time of the continuous casting, the elongation is deteriorated due to the increase in content of solid Ti, and addition amount of Ti becomes very low in comparison to the content of C+N. When the ratio of Ti/(C+N) becomes low, intergranular corrosion occurs so that the corrosion resistance is deteriorated. Therefore, addition amount of Ti is limited to be 0.5% or less, and the ratio of Ti/(C+N) is limited to be in a range of 15 to 20 in consideration of the corrosion resistance and the formability.
When Ca, Mg, and Zr are added singly or in combination of two thereof, a crystal particle size in heat affected zone at the time of TIG welding becomes fine, to lower Ductile-Brittle Transition Temperature (DBTT), thereby raising the pipe expanding properties of a welded portion of a TIG pipe at a low temperature like winter. However, when addition amounts of them become too much, generation amount of oxidative inclusions of Ca, Mg, and Zr increases so that the corrosion resistance is deteriorated. Therefore, the addition amount of Ca is limited to be 0.005% or less, the addition amount of Mg is limited to be 0.005% or less, and the addition amount of Zr is limited to be 0.01% or less.

When an EL value in EL calculation equation found in order to improve the elongation in the present invention becomes less than 33, it is lacking in the elongation and the stretchability as a muffler material of a stamping type. Accordingly, fracture occurs at the time of forming. Therefore, the EL value is limited to be 33 or more.

\[
\text{EL} = -162.1x(C+N)-0.2xCr-1.1xMo-0.2xTi/(C+N)+42.2 \quad (1)
\]

Also, when a pitting index (P.I.) value in Equation 2 becomes high, the corrosion resistance is improved. Therefore, in order to raise the P.I. value, it is necessary to raise the content of Cr or the content of Mo which is an expensive element. However, when the contents of them become excessively high, the elongation and the stretchability are deteriorated while the fabrication cost is raised. Also, when they are too low, the corrosion resistance is deteriorated. Therefore, in order to have the corrosion resistance and the fabrication cost which is a middle degree between a previously used STS409L steel and 439 steel, the P.I. value in the P.I. calculation equation (2) is limited to be in a range of 14 to 16.

\[
\text{P.I.} = \text{Cr}+3.3\text{Mo} \quad (2)
\]

For the ratio of Ti/(C+N), when the ratio of Ti/(C+N) becomes too low, the intergranular corrosion occurs at a welded portion after welding. On the contrary, when it becomes too high, the content of the solid Ti is raised so that the formability such as the elongation, etc., is deteriorated. Therefore, the ratio of Ti/(C+N) is limited to be in a range of 15 to 20.

Next, a fabrication condition of the present invention and a limitation reason thereof will be described.

In a hot rolling condition, as heating temperature of the slab becomes high, it is advantageous for recrystallization during hot rolling operation. However, when the heating temperature is too high, the surface defect occurs. Therefore, the heating temperature of the slab is limited to be in a range of 1230 to 1280°C.

As finishing rolling temperature at the time of hot rolling becomes low, variation accumulation energy during the hot rolling becomes high to help the recrystallization at the time of annealing. Accordingly, a low finishing rolling temperature is ad-
vantageous for elongation improvement. However, when the finishing rolling
temperature becomes too low, sticking surface defect occur due to adhesion of a rolling
roll and a material. Therefore, the finishing rolling temperature is limited to be in a
range of 740 to 850°C.

Also, when the cold reduction ratio of the material becomes too low, it is difficult to
remove the surface defect and to secure the surface properties. On the contrary, when it
becomes high, it is advantageous for improvement of formability. Therefore, the cold
reduction ratio is limited to be 50% or more at the time of material manufacturing.

Since elongation is the most excellent when ASTM crystal particle size number
within annealed steel after cold annealing is in a range of 6.0 to 7.0, it is limited within
this range.

Hereinafter, the present invention will be described in detail through an embodiment.

(Embodiment)

In Table 1, chemical component by specimen, an EL calculation value, and a P.I.
calculation value have been indicated. In Table 2, measured elongations by specimen,
nominal potential, intergranular corrosion generation existence or non-existence,
Ductile-Brittle Transition Temperature (DBTT) at a welded portion of a TIG pipe, and
an Erichsen value have been indicated.

An ingot with a thickness of 120mm was manufactured by melting the ferritic
stainless steel composed as in Table 1 below in a vacuum melting equipment of 50Kg.
The ingot manufactured as described above was heated at 1250°C, and hot rolled at a
finishing rolling temperature of 800°C to manufacture a hot rolled steel with a
thickness of 3.0mm. Then, it was hot annealed at 960°C and then acid-cleaned, to be
cool rolled into a thickness of 1.5mmt and 0.6mmt. Thereafter, it was cool annealed at
960°C and then acid cleaned. A tension test and an Erichsen test were performed and
crystal particle size of the cool annealed steel was measured using an image analyzer.

The nominal potential of the cool annealed steel was tested by a KS D 0238 method
and measured five times at V C 10 to indicate it as a mean value.

The Ductile-Brittle Transition Temperature was measured by processing the cool
annealed steel (a steel to which Cr, Zr, Mg are added and a steel to which they are not
added) with a thickness of 1.5mm to V notch impact specimen with server size and
measuring impact test temperature in intervals of 10°C in a range of +20 to -70°C.
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<th>S</th>
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Table 2
Hereinafter, a test result will be described. Table 1 and Table 2 indicate the chemical component by specimen, the EL and P.I. calculation values, the corrosion resistance (nominal potential), and the stretchability (Erichsen value), etc. In the inventive steel, the contents of Cr and Mo were adjusted so that the P.I. value is in a range of 14 to 16 using Equation 2, which is an equation calculating the P.I. value, and product properties of the middle degree of the conventional steel (409: No. 13, 439 steel: Mo. 14) have been indicated. Also, in the inventive steel, the contents of C, N, Cr, Mo, and Ti/(C+N) were adjusted so that the EL value is 33 or more using Equation 1, which is an equation calculating the EL value. Accordingly, it is appreciated that in the inventive steel, the corrosion resistance is excellent, measured elongation is high as

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much as 34% or more, and Erichson value indicating the stretchability also is high as much as 9.3mm or more. Also, it is appreciated that in the inventive steel having the ratio of Ti(C+N) adjusted in the range of 15 to 20, the intergranular corrosion at the welded portion does not occur as compared to the comparative example out of this range.

FIG. 1 is a view showing a change in the elongation according to a change in ASTM crystal particle size of the annealed steel after cold annealing in 15Cr-Ti (specimen No. 1) steel. It is appreciated from FIG. 1 that the elongation is the most excellent in the ASTM crystal particle size number within the range of 6.0 to 7.0 at the time of the cool annealing.

FIG. 2 is a view showing a change of the elongation after the cool annealing according to the ratio of Ti/(C+N) in the 15Cr-Ti added steel, wherein as the ratio of Ti(C+N) is low, the elongation is excellent. However, when the ratio of Ti/(C+N) become less than 15, the intergranular corrosion at the welded portion occurs as in a result of Table 1, and when the ratio of Ti/(C+N) exceeds 20, the elongation is deteriorated. Therefore, it is required to add Ti while adjusting the ratio of Ti/(C+N) in the range of 15 to 20 in consideration of the intergranular corrosion at the welded portion and the elongation.

FIG. 3 is a view showing a change of the Ductile-Brittle Transition Temperature (DBTT) according to addition or non-addition of Ca, Mg, and Zr in the 15Cr-Ti added steel, wherein when Ca is added, Ca and Mg are added together, or Ca and Zr are added together, the Ductile-Brittle Transition Temperature (DBTT) is low as much as \(-50^\circ C\), so that in the case where working temperature is low like winter, TIG pipe expanding properties becomes excellent.

An optimal embodiment of the present invention has been disclosed through the specific description and the drawings as above. Terms were used in order to describe the present invention, rather than limitation of meaning or limitation of the scope of the present invention described in claims. Therefore, it would be appreciated by those skilled in the art that various modifications and equivalent other embodiments are possible herein. Accordingly, the scope of the present should be defined by technical idea of accompanying claims.
Claims

[1] A low chrome ferritic stainless steel with a high corrosion resistance and stretchability comprising C of 0.03wt% or less, Si of 0.5wt% or less, Mn of 0.5wt% or less, P of 0.035wt% or less, S of 0.01wt% or less, Cr of 14 to 16wt%, Mo of 0.2wt% or less, N of 0.030wt% or less, Cu of 0.5wt% or less, remaining Fe, and inevitably added impurities, being controlled in EL value defined by Equation 1 below to be 33 or more and in P.I. value defined by Equation 2 below to be in a range of 14 to 16:

\[ EL = -162.1 \times (C+N) - 0.2 \times Cr - 1.1 \times Mo - 0.2 \times Ti / (C+N) + 42.2 \]

(1)

\[ P.I. = Cr + 3.3 \times Mo \]  

(2).

[2] The low chrome ferritic stainless steel with the high corrosion resistance and stretchability according to claim 1, comprising one or two or more selected from a group consisting of Ca of 0.005wt% or less, Mg of 0.005wt% or less, and Zr of 0.01wt% or less.

[3] The low chrome ferritic stainless steel with the high corrosion resistance and stretchability according to claim 1 or claim 2, wherein the ratio of Ti/(C+N) is in a range of 15 to 20.


- hot rolling a slab of the ferritic stainless steel according to any one of claims 1 to 3 at a heating temperature of 1230 to 1280°C and a finishing rolling temperature of 740 to 850°C;
- hot annealing the slab at 900 to 1000°C;
- cold annealing the slab at 900 to 1000°C to have a cold reduction ratio 50% or more; and
- adjusting the slab to have a particle size of a range of 6.0 to 7.0 in ASTM crystal particle size number.
A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/18(2006.01)

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)
IPC C21D 6/00, C21D 8/02, C22C 38/00, C22C 38/18, C22C 38/26, C22C 38/28, C22C 38/32, C22C 38/5

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 since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS(KIPO internal) & keywords stretchability, ferritic stainless steel and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>JP 10-121205 A (KAWASAKI STEEL CORP ) 12 May 1998 See the abstract, claims 1-6, paragraphs 34-37, and examples</td>
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<td>KR 10-2004-01 10644 A (POSCO) 31 December 2004 See the abstract, and claims 1-4</td>
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Further documents are listed in the continuation of Box C  See patent family annex

* Special categories of cited documents  
"A" document defining the general state of the art which is not considered to be of particular relevance  
"E" earlier application or patent but published on or after the international filing date  
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)  
"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  
23 FEBRUARY 2009 (23 02 2009)

Date of mailing of the international search report  
23 FEBRUARY 2009 (23.02.2009)

Name and mailing address of the ISA/KR  
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Authorized officer  
LEE, SUNG JOON

Facsimile No 82-42-472-7140

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Form PCT/ISA/210 (second sheet) (July 2008)
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