



(11) **EP 2 733 228 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
21.05.2014 Bulletin 2014/21

(21) Application number: **11869574.1**

(22) Date of filing: **15.07.2011**

(51) Int Cl.:
C22C 38/00 (2006.01) **C21D 8/02** (2006.01)
B21B 3/00 (2006.01) **C21D 9/46** (2006.01)
C23C 2/04 (2006.01) **C22C 38/58** (2006.01)

(86) International application number:
PCT/KR2011/005242

(87) International publication number:
WO 2013/012103 (24.01.2013 Gazette 2013/04)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(71) Applicant: **Posco**
Pohang
Kyongsangbook-do 790-300 (KR)

(72) Inventors:
• **LEE, Kyoo-Young**
Gwangyang-si
Jeollanam-do 545-711 (KR)
• **OH, Jin-Keun**
Gwangyang-si
Jeollanam-do 545-711 (KR)

• **KIM, Jong-Sang**
Gwangyang-si
Jeollanam-do 545-711 (KR)
• **HAN, Tae-Kyo**
Gwangyang-si
Jeollanam-do 545-711 (KR)

(74) Representative: **Powell, Timothy John**
Potter Clarkson LLP
Patents
The Belgrave Centre
Talbot Street
Nottingham Nottinghamshire NG1 5GG (GB)

(54) **HOT PRESS FORMING STEEL PLATE, FORMED MEMBER USING SAME, AND METHOD FOR MANUFACTURING THE PLATE AND MEMBER**

(57) The present invention relates to a hot press forming steel plate made of a composition comprising: 0.3-1.0 wt % of C; 0.01-4.0 wt % of Mn; 1.0-2.0 wt % of Si; 0.01-2.0 wt % of Al; 0.015 wt % or less of S; 0.01 wt % or less of N; and the remainder being Fe and unavoidable impurities. Further, the present invention relates to a method for manufacturing the hot press forming steel plate, characterized by comprising the steps of: heating, to between 1100 and 1300°C, a steel slab having the composition; performing hot rolling finishing between an Ar3 transformation point and 950°C; and performing winding between MS and 720°C. Further, the present invention relates to a hot press formed member charac-

terized by having the composition, and having a dual phase microstructure made of bainite and residual austenite. In addition, the present invention relates to a method for manufacturing the hot press formed member, characterized by comprising the steps of: heating the steel plate having the composition to a temperature of an Ac3 point or higher; hot press molding the heated steel plate; performing cooling at a cooling speed of 20°C/sec or higher to a temperature between MS and 550°C; and performing a heat treatment in a heating furnace between MS and 550°C.

EP 2 733 228 A1

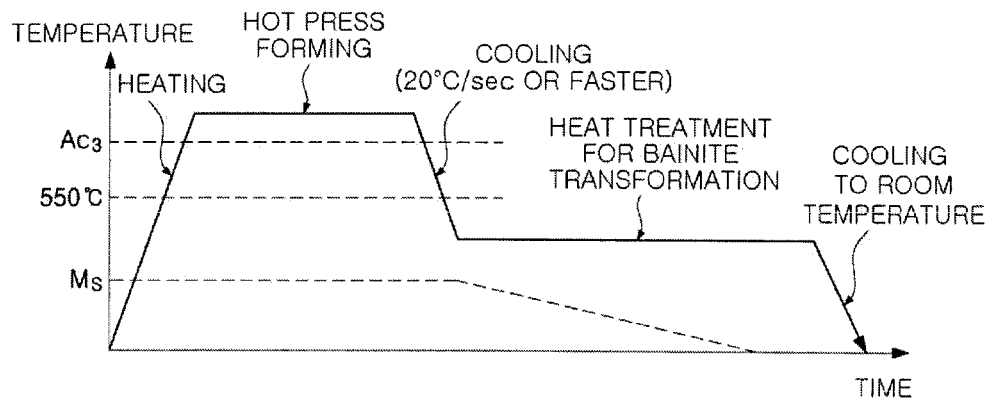


FIG. 1

Description

[Technical Field]

[0001] The present disclosure relates to a steel sheet for hot press forming, a member formed using the steel sheet, and methods for manufacturing the steel sheet and the member, and more particularly, to a steel sheet for manufacturing high-strength and high-ductility products suitable for impact members and crashworthy members of automobiles through a hot press forming process, a member formed using the steel sheet, and methods of manufacturing the steel sheet and the member.

[Background Art]

[0002] Recently, safety regulations for protecting automobile occupants and fuel efficiency regulations for protecting the environment have been greatly tightened, and social requirements for vehicle weight reductions have markedly increased. The use of high-strength steel sheets is necessary to reduce the weight of automotive parts while maintaining the rigidity thereof and the crash safety of automobiles.

[0003] However, if steel sheets for automobiles are improved in strength, the yield strength thereof is inevitably increased, and the elongation thereof is reduced. These factors significantly lower the formability of such steel sheets. In addition, due to excessive spring-back in high-strength steel sheets, the dimensions of components formed of high-strength steel sheets may be varied after a forming process. That is, the shape fixability of components may be lowered.

[0004] To address these limitations, advanced high strength steel (AHSS), such as dual phase (DP) steel in which martensite is included in a ferrite matrix to lower the yield ratio thereof and transformation induced plasticity (TRIP) steel in which bainite and retained austenite are included in a ferrite matrix to markedly increase the strength-elongation balance thereof, have been developed and commercialized.

[0005] However, such steel sheets have a tensile strength of about 500 MPa to 1,000 MPa which may be insufficient to satisfy current rigidity and crash safety requirements while allowing for the lightening of automobiles.

[0006] Therefore, a steel forming method known as hot press forming has been commercialized to overcome such limitations and realize ultra high-strength automotive components. In the hot press forming method, after blanking, a steel sheet is subjected to heating to an A_{c3} temperature or higher for transformation into austenite, extracting, press forming, and die quenching, so as to form a martensite or mixed martensite-bainite microstructure. Ultra high-strength members having a tensile strength of 1 GPa or greater and high dimensional precision owing to high-temperature forming can be obtained using the hot press forming method.

[0007] Although such a hot press forming method of the related art is suitable for satisfying rigidity and crash safety requirements while lightening automotive components, final products have an elongation of 10% or less. That is, final products have a very low level of ductility. In other words, components manufactured by a hot press forming method may be used as impact members in automobiles, but may not be suitable for use as crashworthy members that absorb crash energy to protect vehicle occupants in a crash.

[0008] Therefore, to use hot-press formed members as crashworthy members of automobiles, research into members having a high degree of ductility after being hot-press formed and steel sheets for forming such members through a hot press forming process is required.

[Disclosure]

[Technical Problem]

[0009] Aspects of the present disclosure may provide a steel sheet for manufacturing a hot-press formed member having high strength and high ductility, a member formed using the steel sheet, and methods for manufacturing the steel sheet and the member.

[Technical Solution]

[0010] According to an aspect of the present disclosure, a steel sheet for hot press forming may include, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities.

[0011] According to another aspect of the present disclosure, a method for manufacturing a steel sheet for hot press forming may include: heating a steel slab to a temperature within a range of 1100°C to 1300°C, the steel slab including, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities; performing a finish hot-rolling process at a temperature within a

range of an Ar_3 transformation point to 950°C to form a steel sheet; and coiling the steel sheet at a temperature within a range of M_s to 720°C.

[0012] According to another aspect of the present disclosure, a hot-press formed member may include, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities, wherein the hot-press formed member has a dual phase microstructure formed by bainite and retained austenite.

[0013] According to another aspect of the present disclosure, a method for manufacturing a hot-press formed member may include: heating a steel sheet to a temperature equal to or higher than Ac_3 , the steel sheet including, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities; hot-press forming the heated steel sheet; cooling the hot-press formed steel sheet to a temperature within a range of M_s to 550°C at a rate of 20°C/sec or higher; and heat-treating the cooled steel sheet at a temperature within a range of M_s to 550°C in a heating furnace.

[Advantageous Effects]

[0014] The present disclosure provides a high-strength, high-ductility steel sheet for hot press forming. The present disclosure also provides a member formed using the steel sheet and having a dual phase microstructure constituted by bainite and retained austenite and a $TS(MPa) \cdot EI(\%)$ value of 25,000 MPa% or greater. Since the member has high ductility as well as high strength, the member may be usefully used as a crashworthy member of an automobile.

[Description of Drawings]

[0015]

FIG. 1 is a temperature-time graph illustrating manufacturing processes of a hot-press formed member according to an embodiment of the present disclosure.

FIGS. 2A to 2C are images showing microstructures of hot-press formed members according to cooling rates after a forming process in a method for manufacturing a hot-press formed member, in which FIG. 2A is the case of a cooling rate of 30°C/sec, FIG. 2B is the case of a cooling rate of 5°C/sec, and FIG. 2C is an enlarged image of FIG. 2B.

[Best Mode]

[0016] Embodiments of the present disclosure provide a method for manufacturing a formed member having a high degree of ductility as well as high strength for use as a crashworthy member of an automobile, and a steel sheet having a high degree of ductility for use in manufacturing such a formed member. In detail, the present disclosure provides four categories: a steel sheet for hot press forming having a high degree of ductility, a method for manufacturing the steel sheet, a hot-press formed member, and a method for manufacturing the hot-press formed member.

(Steel sheet for hot press forming)

[0017] Hereinafter, a steel sheet for hot press forming will be described in detail according to an embodiment of the present disclosure.

[0018] The steel sheet for hot press forming has a high degree of ductility as well as a high degree of strength so that a member formed of the steel sheet through a hot press forming process may have a high degree of ductility and a high degree of strength. The steel sheet for hot press forming includes, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities.

[0019] Carbon (C) is an element included in the steel sheet to enhance the strength thereof. Furthermore, in the embodiment of the present disclosure, carbon (C) is diffused into retained austenite by elements such as silicon (Si) to stabilize the retained austenite and thus to prevent transformation to martensite. The steel sheet for hot press forming may include 0.3 wt% to 1.0 wt% of carbon (C). If the carbon content is less than 0.3%, the amount of retained austenite is low after forming, and thus it may be difficult to guarantee both strength and ductility. If the carbon content is greater than 1.0%, bainite transformation is markedly slowed, and the formation of pearlite is facilitated, thereby deteriorating properties of the steel sheet.

[0020] Manganese (Mn) is included in the steel sheet to prevent red shortness caused by FeS formed by sulfur (S) inevitably included in the steel sheet during a manufacturing process. The content of manganese (M) may be within the range of 0.01% to 4.0%. If the content of manganese (M) is less than 0.01%, red shortness may be caused by FeS. If the content of manganese (M) is greater than 4.0%, bainite transformation may be slowed to increase the time required for a heat treatment in a hot press forming process. As a result, the productivity of the hot press forming process may

be lowered, and the manufacturing cost of the steel sheet may be increased.

[0021] Silicon (Si) is an element included in the steel sheet to guarantee the ductility of a final product. Silicon (Si) facilitates ferrite transformation and diffuses carbon (C) into retained austenite to stabilize the retained austenite by an increased amount of carbon (C) in the retained austenite, thereby preventing transformation to martensite. The content of silicon (Si) may be within the range of 1.0 wt% to 2.0 wt%. If the content of silicon (Si) is less than 1.0%, the effect of stabilizing retained austenite may be poor. If the content of silicon (Si) is greater than 2.0%, the rolling characteristics of the steel sheet may be deteriorated. For example, the steel sheet may be cracked during a rolling process. Therefore, the upper limit of the content of silicon (Si) is set as 2.0%.

[0022] Aluminum (Al) removes oxygen from the steel sheet to prevent the inclusion of nonmetallic substances therein during solidification. In addition, like silicon (Si), aluminum (Al) facilitates the diffusion of carbon (C) into retained austenite to stabilize the retained austenite. The content of aluminum (Al) may be within the range of 0.01% to 2.0%. If the content of aluminum (Al) is less than 0.01%, oxygen may be insufficiently removed, and thus it may be difficult to prevent the inclusion of nonmetallic substances. If the content of aluminum (Al) is greater than 2.0%, the unit cost of steel making may be increased.

[0023] Sulfur (S) is an element inevitably included in the steel sheet during a manufacturing process thereof. Sulfur (S) combines with iron (Fe) to form FeS causing red shortness. Therefore, it may be necessary to keep the content of sulfur (S) as low as possible. For example, the content of sulfur (S) may be limited to 0.015% or less. Nitrogen (N) is an element inevitably included in the steel sheet during a manufacturing process. The content of nitrogen (N) may be kept as low as possible. For example, the content of nitrogen (N) may be limited to 0.01% or less.

[0024] In addition to the above-mentioned elements, the steel sheet for hot press forming may further include at least one element selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.

[0025] Molybdenum (Mo) may be added to the steel sheet to suppress the formation of pearlite. Since molybdenum (Mo) is relatively expensive and may increase the manufacturing cost of the steel sheet, 0.5 wt% or less of molybdenum (Mo) may be added.

[0026] Chromium (Cr) may be added to the steel sheet to suppress the formation of ferrite and expand bainite transformation. If the content of chromium (Cr) is greater than 1.5 wt%, chromium carbide may be formed to lower the amount of dissolved carbon (C). Therefore, 1.5 wt% or less of chromium (Cr) may be added.

[0027] Nickel (Ni) may be added to increase the fraction of austenite and the hardenability of the steel sheet. Since nickel (Ni) is expensive and increases the manufacturing cost of the steel sheet, 0.5 wt% or less of nickel (Ni) may be added.

[0028] Niobium (Nb) may be added to improve the strength, grain refining characteristics, and ductility of the steel sheet. During reheating, niobium (Nb) suppresses grain growth, and during cooling, niobium (Nb) delays transformation of austenite into ferrite. 0.005 wt% to 0.1 wt% of niobium (Nb) may be added. If the content of niobium (Nb) is less than 0.005%, it is difficult to assure the effect of grain refinement, and if the content of niobium (Nb) is greater than 0.1%, carbonitrides may excessively precipitate to cause delayed fractures in the steel sheet or decrease the workability of the steel sheet.

[0029] Vanadium (V) may be added to improve the strength, grain refining characteristics, and hardenability of the steel sheet. 0.005 wt% to 0.1 wt% of vanadium (V) may be added. If the content of vanadium (V) is less than 0.005%, such effects may not be obtained, and if the content of vanadium (V) is greater than 0.1%, carbonitrides may excessively precipitate to cause delayed fractures in the steel sheet or decrease the workability of the steel sheet.

[0030] In addition, the steel sheet for hot press forming may further include B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

[0031] Boron (B) may be added to suppress the formation of ferrite. If the content of boron (B) is greater than 0.005 wt%, boron (B) may combine with iron (Fe) or carbon (C) to form a compound facilitating the formation of ferrite. Therefore, 0.005 wt% or less of boron (B) may be added.

[0032] Titanium (Ti) may be added to maximize the effect of boron (B). Titanium (Ti) combines with nitrogen (N) existing as an impurity in the steel sheet to form TiN, and thus boron (B) may not combine with nitrogen (N). Therefore, the formation of ferrite may be suppressed by boron (B). This effect may be assured by adding 0.06 wt% or less of titanium (Ti).

[0033] The steel sheet may be a hot-rolled or cold-rolled steel sheet. For example, the steel sheet may be a cold-rolled steel sheet coated with a plating layer for improving corrosion resistance and suppressing the formation of a surface oxide layer.

[0034] According to the embodiment of the present disclosure, since the steel sheet for hot press forming has high strength and high ductility owing to the above-described composition, the steel sheet may be usefully used to manufacture hot-press formed members (described later) having high strength and ductility.

(Method for manufacturing steel sheet for hot press forming)

[0035] Hereafter, a method for manufacturing a steel sheet for hot press forming will be described in detail according

to an embodiment of the present disclosure. This embodiment is an exemplary example for manufacturing a steel sheet suitable for manufacturing a hot-press formed member having improved ductility.

[0036] The method for manufacturing a steel sheet for hot press forming includes: heating a steel slab to a temperature within a range of 1100°C to 1300°C, the steel slab including, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities; performing a finish hot-rolling process at a temperature within a range of A_{r3} transformation point to 950°C to form a steel sheet; and coiling the steel sheet at a temperature within a range of M_s to 720°C.

[0037] If the steel slab is heated to a temperature lower than 1100°C, the continuous-casting structure of the steel slab may be insufficiently uniformized, and it may be difficult to assure a finish rolling temperature. If the steel slab is heated to a temperature greater than 1300°C, the size of crystal grains and the possibility of surface oxidation may increase to deteriorate the strength and surface properties of the steel slab. Therefore, the steel slab may be heated to a temperature within a range of 1100°C to 1300°C. If the finish hot-rolling temperature is lower than A_{r3} transformation point, dual phase rolling may occur to result in hot-rolling mixed grain sizes, and if the finish hot-rolling temperature is higher than 950°C, crystal grains may be coarsened and surface oxidation may occur during the finish hot-rolling process. Therefore, the finish hot-rolling temperature may be within the range of the A_{r3} transformation point to 950°C. In addition, if the coiling temperature is lower than M_s , austenite may transform to martensite to decrease the ductility of the steel sheet and thus to make it difficult to perform a hot coiling process on the steel sheet. If the coiling temperature is higher than 720°C, a thick surface oxide layer may be formed on the steel sheet together with internal oxidation in the steel sheet. Therefore, the coiling temperature may be within the range of M_s to 720°C.

[0038] The method for manufacturing a steel sheet for hot press forming may include: heating a steel slab to a temperature within a range of 1100°C to 1300°C, the steel slab including, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities; performing a finish hot-rolling process at a temperature within a range of A_{r3} transformation point to 950°C to form a steel sheet; coiling the steel sheet at a temperature within a range of M_s to 720°C; pickling the steel sheet; cold-rolling the steel sheet; continuously annealing the steel sheet at a temperature within a range of 750°C to 900°C; and overaging the steel sheet at a temperature within a range of M_s to 550°C.

[0039] The pickling of the steel sheet is performed to remove surface oxides formed during the heating and finish hot-rolling processes. Thereafter, the cold-rolling process is performed. If the continuous annealing temperature for the cold-rolled steel sheet is lower than 750°C, recrystallization may occur insufficiently, and thus a desired degree of workability of the steel sheet may not be obtained. If the continuous annealing temperature is higher than 900°C, it may difficult to heat the steel sheet to the continuous annealing temperature due to the limitation of heating equipment. In addition, if the overaging temperature is lower than M_s , martensite may be formed to excessively increase the strength of the steel sheet and negatively affect the ductility of the steel sheet. Therefore, before a hot press forming process, blanking may not be easily performed. If the overaging temperature is higher than 550°C, the processability of the steel sheet may be lowered due to roll surface deterioration in an annealing furnace, and intended carbide precipitation and bainite transformation may not occur in the overaging process.

[0040] The method for manufacturing a steel sheet for hot press forming may include: heating a steel slab to a temperature range of 1100°C to 1300°C, the steel slab including, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities; performing a finish hot-rolling process at a temperature within a range of A_{r3} transformation point to 950°C to form a steel sheet; coiling the steel sheet at a temperature within a range of M_s to 720°C; pickling the steel sheet; cold-rolling the steel sheet; continuously annealing the steel sheet at a temperature within a range of 750°C to 900°C; overaging the steel sheet at a temperature within a range of M_s to 550°C; and plating the overaged steel sheet by any one of hot-dip galvanizing, galvannealing, electro galvanizing, and hot-dip aluminizing.

[0041] A hot-dip galvanized steel sheet may be manufactured by dipping a cold-rolling steel sheet in a galvanizing bath. A galvannealed steel sheet may be manufactured by dipping a cold-rolled steel sheet in a plating bath and performing an alloying heat-treatment process on the steel sheet. An electro-galvanized steel sheet may be manufactured by performing an electro galvanizing process or a Zn-Fe electroplating process on a cold-rolled steel sheet in a continuous electroplating line. A hot-dip aluminized steel sheet may be manufactured by heating a cold-rolled steel sheet, dipping the steel sheet in an aluminum plating bath, and cooling the steel sheet at room temperature at a cooling rate of 5°C/sec to 15°C/sec.

[0042] The steel slab may further include at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%. In addition, the steel slab may further include B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

(Hot-press formed member)

[0043] Hereinafter, a hot-press formed member will be described in detail according to an embodiment of the present

disclosure.

[0044] The hot-press formed member has high ductility and high strength. For this, the hot-press formed member includes, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities. The hot-press formed member may have a microstructure formed of bainite and retained austenite without martensite.

[0045] The hot-press formed member may further include at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%. In addition, the hot-press formed member may further include B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

[0046] Hot-press formed members of the related art are manufactured to have ultra high strength, and thus martensite is requisitely formed therein. However, martensite lowers the ductility of such hot-press formed members and thus makes such hot-press formed members unsuitable to be used as crashworthy members of automobiles. Therefore, in the embodiment of the present disclosure, the formation of martensite in the hot-press formed member is suppressed, and the amount of retained austenite is increased. Thus, the hot-press formed member has dual phases: bainite and retained austenite.

[0047] The hot-press formed member having the above-mentioned composition and microstructure has good strength-ductility balance. For example, TS*E1 of the hot-press formed member may be 25,000 or greater so as to be used as a crashworthy member of an automobile as well as being used as an impact member, where TS denotes tensile strength [MPa] and EI denotes elongation [%].

(Method for manufacturing hot-press formed member)

[0048] Hereinafter, a method for manufacturing a hot-press formed member will be described in detail according to an embodiment of the present disclosure.

[0049] The method is for performing a hot press forming process on the above-described steel sheet to provide an ultra high-strength automotive component having high ductility. For this, the method includes: heating a steel sheet to a temperature equal to or higher than A_{c3} , the steel sheet including, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities; hot-press forming the heated steel sheet; cooling the hot-press formed steel sheet to a temperature range of M_s to 550°C at a rate of 20°C/sec or higher; and heat-treating the cooled steel sheet in a heating furnace heated at a temperature within a range of M_s to 550°C.

[0050] The steel sheet may further include at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%. In addition, the steel sheet may further include B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%). The steel sheet may be one of a hot-rolled steel sheet, a cold-rolled steel sheet, and a plated cold-rolled steel sheet coated with a plating layer.

[0051] In the method for manufacturing a hot-press formed member according to the embodiment of the present disclosure, the heat-treating after the hot-press forming is controlled differently as compared with the case of the related art, so as to manufacture a hot-press formed member having a different microstructure for improving ductility as compared with a hot-press formed member of the related art. That is, in the related art, heat-treatment conditions are adjusted to form martensite as a main microstructure to finally obtain an ultra high-strength member. However, since such a technique of the related art is not suitable to manufacture a highly ductile member usable as a crashworthy member of an automobile, the inventors have suggested heat treatment conditions for forming a microstructure constituted by bainite and retained austenite without martensite.

[0052] First, the steel sheet is heated to a temperature equal to A_{c3} or higher for transformation to austenite, and is then hot-press formed.

[0053] The heat-treatment conditions after the hot-press forming have a major effect on determining the microstructure of a product. In the related art, generally, a hot-press formed steel sheet is directly die-quenched to a temperature equal to or lower than M_s so as to form martensite as a main microstructure in a final product and thus to enhance the strength of the final product.

[0054] However, in the embodiment of the present disclosure, martensite is excluded from the microstructure of a final product so as to improve the ductility of the final product while maintaining the strength of the final product at a level suitable for weight reduction. To this end, instead of cooling the hot-press formed steel sheet directly to room temperature equal to or lower than M_s , the hot-press formed steel sheet is cooled to a temperature range of M_s to 550°C, and heat-treated in a heating furnace at a temperature within a range of M_s to 550°C so as to cause the hot-press formed steel sheet to undergo transformation to bainite. If the steel sheet is cooled to a temperature equal to or lower than M_s , martensite may be formed to lower the ductility of the steel sheet, and if the steel sheet is cooled to a temperature higher than 550°C, pearlite may be formed to deteriorate properties of the steel sheet. Therefore, the cooling rate is adjusted

to be within the range of M_s to 550°C to form a dual phase microstructure constituted by bainite and retained austenite.

[0055] In the bainite formed as described above, Fe_3C carbide may not be formed because elements such as silicon (Si) are sufficiently included in the steel sheet to diffuse carbon (C) into the retained austenite. That is, carbon (C) does not form carbides but is dissolved in the retained austenite to stabilize the retained austenite and thus to lower M_s . Therefore, in the next cooling process, transformation to martensite is suppressed. Therefore, in a final product, the retained austenite remains instead of undergoing transformation to martensite, thereby improving ductility.

[0056] The cooling rate may be 20°C/sec or higher. If the cooling rate is lower than 20°C/sec, transformation to pearlite may easily occur to lower properties of a final product. Referring to FIG. 2A, bainite was formed at a cooling rate of 30°C/sec. However, referring to FIGS. 2B and 2C, a pearlite structure in which ferrite and Fe_3C were layered was formed at a cooling rate of 5°C/sec.

[0057] For example, the above-described processes for manufacturing a hot-press formed member according to the embodiment of the present disclosure may be summarized as follows. First, a steel sheet is inserted in a heating furnace to heat the steel sheet to A_{c3} or higher for forming austenite, and then the heated steel sheet is hot-press formed. After the hot press forming, the steel sheet is cooled to a temperature range of M_s to 550°C at a cooling rate of 20°C/sec or higher so as not to form pearlite, and is then heat-treated in a heating furnace at a temperature within a range of M_s to 550°C. These processes are for transformation to bainite, and during the processes, carbon (C) diffuses into austenite to lower M_s . Although a hot-press formed member manufactured through the above-described processes is cooled to room temperature without any controlling, transformation to martensite does not occur. That is, a dual phase microstructure constituted by bainite and retained austenite may be obtained.

[0058] Hereinafter, the embodiments of the present disclosure will be described more specifically according to examples. The following examples are merely provided to allow for a clear understanding of the present disclosure, rather than to limit the scope thereof.

[Mode for Invention]

(Examples)

[0059] Steel ingots 90 mm in length and 175 mm in width having compositions shown in Table 1 were manufactured by vacuum melting, and were then re-heated at 1200°C for 1 hour. Thereafter, the steel ingots were hot-rolled to obtain steel sheets having a thickness of 3 mm. At that time, a finish hot-rolling temperature was A_{r3} or higher. Then, after cooling the steel sheets, the steel sheets were inserted into a heating furnace previously heated to 600°C and left in the heating furnace for 1 hour. Thereafter, the steel sheets were cooled in the heating furnace to simulate hot coiling. Next, the steel sheets were cold-rolled at a reduction ratio of 60% to a thickness of 1.2 mm and were annealed at 900°C. Then, the steel sheets were allowed to undergo bainite transformation at 400°C. In Table 1, the contents of elements are given in wt% except for the contents of sulfur (S) and nitrogen (N) given in ppm.

[Table 1]

Steels	C	Si	Mn	Al	Mo	Cr	Ni	Ti	B	Nb	V	S	N
IS* 1	0.40	1.51	3.01	0.04								30	20
IS 2	0.63	1.49	0.72	0.50								20	20
IS 3	0.61	1.52	0.63	0.51			0.30					30	20
IS 4	0.61	1.50	0.65	0.50						0.015		30	20
IS 5	0.62	1.49	1.61	1.53							0.02	30	20
IS 6	0.60	1.50	2.91	0.04	0.25	1.20						20	20
IS 7	0.71	1.47	0.70	0.52				0.010	0.002			20	20
IS 8	0.68	1.48	0.71	0.04	0.24							30	20
IS 9	0.70	1.15	0.72	0.51	0.24							30	20
IS 10	0.71	1.15	0.71	0.04	0.24			0.010	0.002			30	20
IS 11	0.69	1.55	0.18	0.04	0.24	0.50		0.010	0.002			30	20
IS 12	0.82	1.49	0.51	0.54								30	20
IS 13	0.82	1.51	1.01	0.53								30	20

EP 2 733 228 A1

(continued)

Steels	C	Si	Mn	Al	Mo	Cr	Ni	Ti	B	Nb	V	S	N
CS** 1	0.23	1.5	1.5	0.04								30	20
CS 2	0.20	0.5	1.5	0.03								30	20
CS 3	0.22	1.5	2	0.03	0.20							20	20
CS 4	0.68	0.42	0.70	0.52								20	20
*IS: Inventive Steel, **CS: Comparative Steel													

[0060] To simulate a heat treatment in a heating furnace during a hot press forming process, the 1.2 mm thickness steel sheets manufactured as described above were heated to a temperature of 900°C and maintained at the temperature for 30 seconds. Then, the steel sheets were cooled to cooling temperatures at a rate of 30°C/sec. Next, the steel sheets were inserted into a heating furnace and heat-treated in the heating furnace at the same temperatures as the cooling temperatures for 400 seconds to 10,800 seconds. Thereafter, the steel sheets were air-cooled. In this way, hot-press formed members were obtained. The process conditions and mechanical properties of the hot-press formed members are shown in Table 2 below.

[Table 2]

Steels	Cooling Rate (°C/sec)	Cooling Temperature (°C)	Time (sec)	YS (MPa)	TS (MPa)	EI (%)	TS*E1 (MPa%)	M _s (°C)
Is* 1	30	400	3600	732	1265	28	35420	295
IS 2	30	400	3600	899	1187	39	46244	298
IS 3	30	400	3600	869	1196	37	44252	302
IS 4	30	400	3600	915	1289	35	45115	307
IS 5	30	400	3600	883	1185	36	42660	272
IS 6	30	400	10800	856	1420	26	36920	199
	30	300	10800	985	1610	22	35420	199
IS 7	30	400	3600	900	1185	40	46923	273
	5	400	3600	719	1128	11	12408	273
IS 8	30	400	600	816	1310	21	27510	280
IS 9	30	400	600	915	1240	29	35960	277
IS 10	30	400	600	845	1318	25	32950	270
IS 11	30	400	600	940	1288	26	33488	280
IS 12	30	400	3600	881	1229	35	43556	245
IS 13	30	400	3600	725	1306	39	50934	228
CS** 1	30	400	3600	640	1125	15	16875	399
	30	250	3600	1295	1511	6	9066	399
CS 2	30	250	3600	1220	1450	7	10150	420
CS 3	30	250	3600	1280	1490	6	8940	384
CS 4	30	400	3600	870	1201	16	19216	295
*IS: Inventive Steel, **CS: Comparative Steel								

[0061] Since TS*E1 of Comparative Steel 1 cooled at a cooling rate of 400°C is 16,785 MPa%, Comparative Steel 1 is not suitable as a crashworthy member of an automobile. The reason for this may be that the insufficient content of carbon (C) led to failure in stabilizing retained austenite. In the case that the cooling rate was 250°C, Comparative Steel

1 was cooled to a temperature lower than M_s to result in a large amount of transformation to martensite, and thus Comparative Steel 1 had high strength but low ductility. In this case, TS*EI of Comparative Steel 1 is 9,066 MPa%, and Comparative Steel 1 is not suitable to form a crashworthy member of an automobile.

[0062] The carbon (C) content and silicon (Si) content of Comparative Steel 2 are also not sufficient to stabilize retained austenite, and the cooling temperature of Comparative Steel 2 is equal to or lower than M_s to result in transformation to martensite. Therefore, Comparative Steel 2 has low ductility, and TS*EI thereof is low at 10,150 MPa%. Comparative Steel 3 also has an insufficient content of carbon (C), and the cooling temperature of Comparative Steel 3 is equal to or lower than M_s . Therefore, TS*EI of Comparative Steel 3 is low at 8,940 MPa%, and Comparative Steel 3 is not suitable to form a crashworthy member of an automobile.

[0063] Although Comparative Steel 4 has a sufficient content of carbon (C), the silicon (Si) content of Comparative Steel 4 is not sufficient to fully diffuse carbon (C) into retained austenite. Therefore, although TS*EI of Comparative Steel 4 is relatively high at 19,216 MPa% as compared with other comparative steels, TS*EI of Comparative Steel 4 is not greater than 25,000 MPa%. That is, Comparative Steel 4 is not suitable for forming a crashworthy member of an automobile.

[0064] Samples of Inventive Steel 7 having a composition within the range of the present disclosure were cooled at a cooling rate of 30°C/sec and at a cooling rate of 5°C/sec, respectively. In the case that the cooling rate was 30°C/sec, TS*EI of Inventive Steel 7 was high at 46,923 MPa% and suitable for a crashworthy member of an automobile. However, in the case that the cooling rate was 5°C/sec, TS*EI of Inventive Steel 7 was low at 12,480 MPa% and not suitable for a crashworthy member of an automobile. The reason for this may be that the low cooling rate led to the formation of pearlite as shown in FIGS. 2A to 2C and deterioration of properties thereof.

Claims

1. A steel sheet for hot press forming, comprising, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities.
2. The steel sheet for hot press forming of claim 1, further comprising at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.
3. The steel sheet for hot press forming of claim 1 or 2, further comprising B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).
4. The steel sheet for hot press forming of claim 1 or 2, wherein the steel sheet is one of a hot-rolled steel sheet, a cold-rolled steel sheet, and a plated cold-rolled steel sheet coated with a plating layer.
5. A method for manufacturing a steel sheet for hot press forming, the method comprising:
 - heating a steel slab to a temperature range of 1100°C to 1300°C, the steel slab comprising, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities;
 - performing a finish hot-rolling process at a temperature within a range of A_{r3} transformation point to 950°C to form a steel sheet; and
 - coiling the steel sheet at a temperature within a range of M_s to 720°C.
6. The method of claim 5, wherein the steel slab further comprises at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.
7. The method of claim 5 or 6, wherein the steel slab further comprises B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).
8. A method for manufacturing a steel sheet for hot press forming, the method comprising:
 - heating a steel slab to a temperature range of 1100°C to 1300°C, the steel slab comprising, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities;

performing a finish hot-rolling process at a temperature within a range of A_{r3} transformation point to 950°C to form a steel sheet;
 coiling the steel sheet at a temperature within a range of M_s to 720°C;
 pickling the steel sheet;
 cold-rolling the steel sheet;
 continuously annealing the steel sheet at a temperature within a range of 750°C to 900°C; and
 overaging the steel sheet at a temperature within a range of M_s to 550°C.

9. The method of claim 8, wherein the steel slab further comprises at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.

10. The method of claim 8 or 9, wherein the steel slab further comprises B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

11. A method for manufacturing a steel sheet for hot press forming, the method comprising:

heating a steel slab to a temperature range of 1100°C to 1300°C, the steel slab comprising, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities;
 performing a finish hot-rolling process at a temperature within a range of A_{r3} transformation point to 950°C to form a steel sheet;
 coiling the steel sheet at a temperature within a range of M_s to 720°C;
 pickling the steel sheet;
 cold-rolling the steel sheet;
 continuously annealing the steel sheet at a temperature within a range of 750°C to 900°C;
 overaging the steel sheet at a temperature within a range of M_s to 550°C; and
 plating the overaged steel sheet by any one of hot-dip galvanizing, galvannealing, electro galvanizing, and hot-dip aluminizing.

12. The method of claim 11, wherein the steel slab further comprises at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.

13. The method of claim 11 or 12, wherein the steel slab further comprises B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

14. A hot-press formed member comprising, by wt%, C: 0.3% to 1.00, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the balance of Fe and inevitable impurities, wherein the hot-press formed member has a dual phase microstructure formed by bainite and retained austenite.

15. The hot-press formed member of claim 14, further comprising at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.

16. The hot-press formed member of claim 14 or 15, further comprising B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

17. The hot-press formed member of claim 14 or 15, wherein the hot-press formed member has a TS(MPa)*EI(%) value of 25,000 MPa% or greater.

18. The hot-press formed member of claim 16, wherein the hot-press formed member has a TS(MPa)*EI(%) value of 25,000 MPa% or greater.

19. A method for manufacturing a hot-press formed member, the method comprising:

heating a steel sheet to a temperature equal to or higher than A_{c3} , the steel sheet comprising, by wt%, C: 0.3% to 1.0%, Mn: 0.01% to 4.0%, Si: 1.0% to 2.0%, Al: 0.01% to 2.0%, S: 0.015% or less, N: 0.01% or less, and the

balance of Fe and inevitable impurities;
 hot-press forming the heated steel sheet;
 cooling the hot-press formed steel sheet to a temperature range of M_s to 550°C at a rate of 20°C/sec or higher; and
 heat-treating the cooled steel sheet at a temperature within a range of M_s to 550°C in a heating furnace.

5

20. The method of claim 19, wherein the steel sheet further comprises at least one selected from the group consisting of Mo: 0.5% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), Ni: 0.5% or less (excluding 0%), Nb: 0.005% to 0.1%, and V: 0.005% to 0.1%.

10

21. The method of claim 19 or 20, wherein the steel sheet further comprises B: 0.005% or less (excluding 0%) and Ti: 0.06% or less (excluding 0%).

22. The method of claim 19 or 20, wherein the steel sheet is one of a hot-rolled steel sheet, a cold-rolled steel sheet, and a plated cold-rolled steel sheet coated with a plating layer.

15

20

25

30

35

40

45

50

55

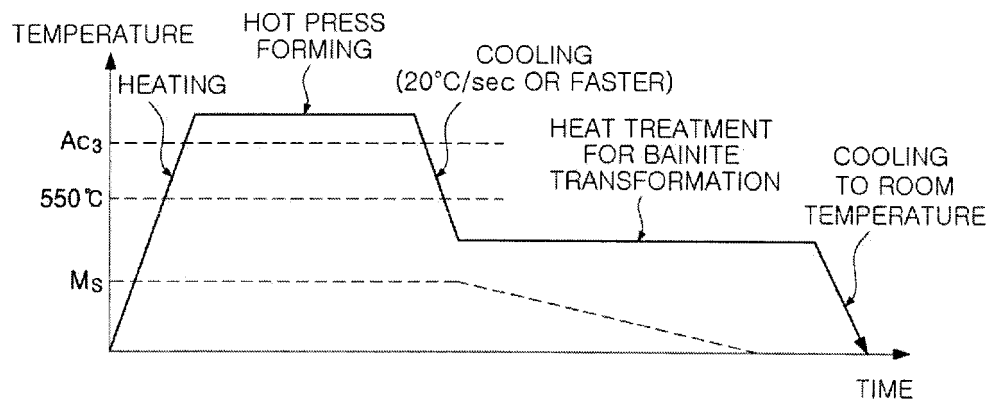


FIG. 1

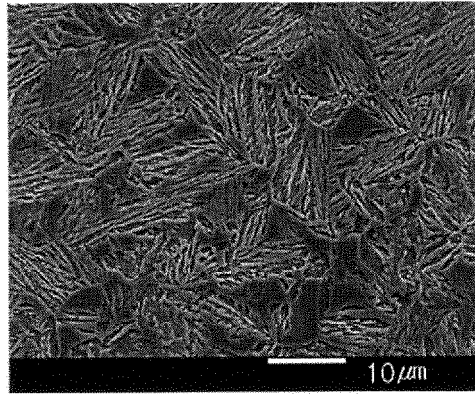


FIG. 2A

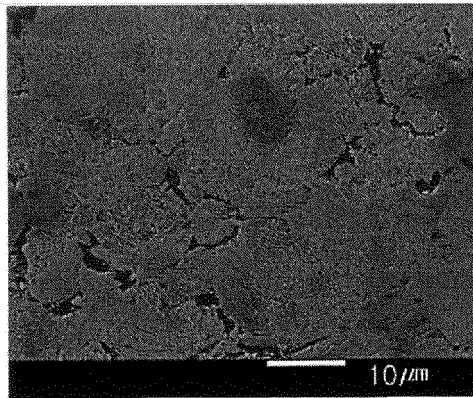


FIG. 2B

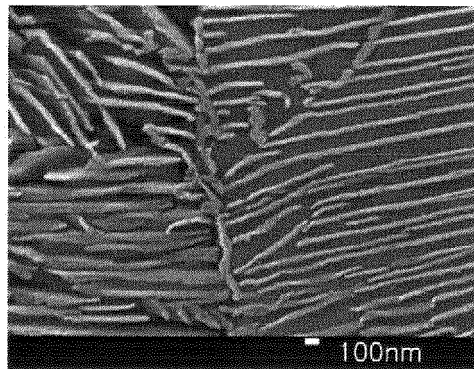


FIG. 2C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2011/005242

A. CLASSIFICATION OF SUBJECT MATTER C22C 38/00(2006.01)i, C21D 8/02(2006.01)i, B21B 3/00(2006.01)i, C21D 9/46(2006.01)i, C23C 2/04(2006.01)i, C22C 38/58(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C22C 38/00; C21D 9/46; C21D 1/74; C22C 38/38; C22C 38/04 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean Utility models and applications for Utility models: IPC as above Japanese Utility models and applications for Utility models: IPC as above Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS (KIPO internal) & Keywords: hot press forming, high strength, orientation, over aging		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007-113100 A (NIPPON STEEL CORP) 10 May 2007 See abstract, claims 1 - 5 and paragraphs [0032] - [0038].	1-7
A	JP 2007-113100 A (NIPPON STEEL CORP) 10 May 2007 See abstract, claims 1 - 5 and paragraphs [0032] - [0038].	8-22
X	KR 10-2010-0091243 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 18 August 2010 See abstract, claims 1 - 8 and paragraph [0115].	1-7
A	KR 10-2010-0091243 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 18 August 2010 See abstract, claims 1 - 8 and paragraph [0115].	8-22
A	WO 2007-129676 A1 (SUMITOMO METAL INDUSTRIES, LTD. et al.) 15 November 2007 See abstract and claims 1 - 17.	1-22
A	KR 10-2009-0101684 A (POSCO) 29 September 2009 See abstract and claims 1 - 15.	1-22
☐ 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 another 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 12 MARCH 2012 (12.03.2012)		Date of mailing of the international search report 13 MARCH 2012 (13.03.2012)
Name and mailing address of the ISA/KR  Korean Intellectual Property Office Government Complex-Daejeon, 139 Seonsa-ro, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140		Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2011/005242

Patent document cited in search report	Publication date	Patent family member	Publication date
JP 2007-113100 A	10.05.2007	JP 4495064 B2	30.06.2010
KR 10-2010-0091243 A	18.08.2010	CA 2581251 A1	23.03.2006
		CA 2701559 A1	23.03.2006
		EP 1790422 A1	30.05.2007
		EP 2266722 A1	29.12.2010
		JP 04-551169 B2	16.07.2010
		JP 04-551300 B2	16.07.2010
		JP 2006-082099 A	30.03.2006
		JP 2006-110713 A	27.04.2006
		JP 2006-111966 A	27.04.2006
		JP 4551169 B2	22.09.2010
		JP 4551300 B2	22.09.2010
		KR 10-2007-0043891 A	25.04.2007
		KR 10-2010-0091244 A	18.08.2010
		US 7842142 B1	30.11.2010
		WO 2006-030971 A1	23.03.2006
WO 2007-129676 A1	15.11.2007	CN 101484601 A	15.07.2009
		KR 10-2008-0111549 A	23.12.2008
KR 10-2009-0101684 A	29.09.2009	CN 101545071 A	30.09.2009
		US 2009-0238715 A1	24.09.2009

Form PCT/ISA/210 (patent family annex) (July 2009)