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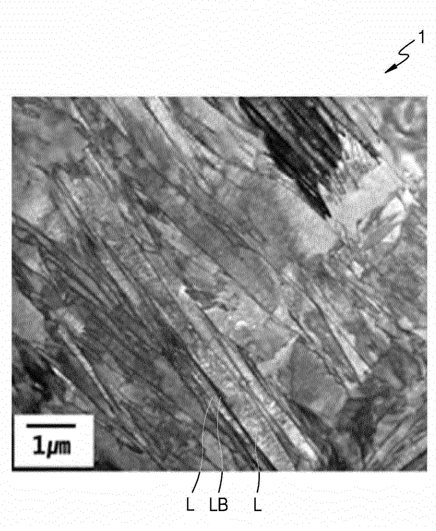
(54) HOT-STAMPED PART

(57) Provided is a hot-stamped part including a base steel sheet, the base steel sheet including an amount of about 0.19 to about 0.25 wt% of carbon (C), an amount of about 0.1 to about 0.6 wt% of silicon (Si), an amount of about 0.8 to about 1.6 wt% of manganese (Mn), an amount of about 0.03 wt% or less of phosphorus (P), an amount of about 0.015 wt% or less of sulfur (S), an amount of about 0.1 to about 0.6 wt% of chromium (Cr), an amount of about 0.001 to about 0.005 wt% of boron (B), an amount of about 0.1 wt% or less of an additive, remaining iron (Fe), and other unavoidable impurities. In an indentation strain rate with respect to an indentation depth of about 200 nm to about 600 nm is observed in a nano indentation test, a number of indentation dynamic strain aging (DSA) is about 26 to about 40.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a hot stamped part.

BACKGROUND

[0002] As environmental and fuel economy regulations are strengthened around the world, a need for light vehicle materials is increasing. Accordingly, research and development on ultra-high strength steel and hot stamping steel are being actively carried out. In this context, a hot stamping process is generally made of heating/forming/cooling/trimming, and includes phase transformation of a material and a change of a micro-structure during the process.

[0003] Recently, study to improve delayed fracture, corrosion resistance, and weldability in a hot-stamped part manufactured by the hot stamping process has been actively performed. As a related technology, there is Korean Patent Publication No. 10-2018-0095757 (Invention Title: Method of Manufacturing Hot Stamped Part), etc.

SUMMARY

Technical Problem

[0004] The present disclosure provides a hot-stamped part with improved crashworthiness.

[0005] However, the problem is an example, and the scope of the present disclosure is not limited thereto.

Technical Solution

[0006] According to an aspect of the present disclosure, a hot-stamped part includes a base steel sheet, the base steel sheet including an amount of about 0.19 to about 0.25 wt% of carbon (C), an amount of about 0.1 to about 0.6 wt% of silicon (Si), an amount of about 0.8 to about 1.6 wt% of manganese (Mn), an amount of about 0.03 wt% or less of phosphorus (P), an amount of about 0.015 wt% or less of sulfur (S), an amount of about 0.1 to about 0.6 wt% of chromium (Cr), an amount of about 0.001 to about 0.005 wt% of boron (B), an amount of about 0.1 wt% or less of an additive, remaining iron (Fe), and other unavoidable impurities. In an indentation strain rate with respect to an indentation depth of about 200 nm to about 600 nm observed in a nano indentation test, a number of indentation dynamic strain aging (DSA) is about 26 to about 40.

[0007] According to an exemplary embodiment, the base steel sheet may include a martensite structure in which a plurality of lath structures are distributed.

[0008] According to an exemplary embodiment, an average interval between a plurality of laths may be about 140 nm to about 300 nm.

[0009] According to an exemplary embodiment, the hot-stamped part may further include fine precipitates distributed in the base steel sheet, in which the fine precipitates include a nitride or a carbide of at least any one of titanium (Ti), niobium (Nb), and vanadium (V).

[0010] According to an exemplary embodiment, a number of fine precipitates distributed per unit area (100 μm^2) may be about 7,500 to about 18,000.

[0011] According to an exemplary embodiment, an average diameter of the fine precipitates may be about 0.0068 μm or less.

[0012] According to an exemplary embodiment, a rate of fine precipitates having a diameter of about 0.01 μm or less among the fine precipitates may be about 63 % or greater.

[0013] According to an exemplary embodiment, a rate of fine precipitates having a diameter of about 0.005 μm or less among the fine precipitates may be about 28 % or greater.

[0014] According to an exemplary embodiment, a V-bending angle of the hot-stamped part may be equal to or greater than about 50°.

[0015] According to an exemplary embodiment, a tensile strength of the hot-stamped part may be equal to or greater than about 1350 MPa.

[0016] According to an exemplary embodiment, an amount of activation hydrogen of the hot-stamped part may be about 0.8 wppm or less.

Advantageous Effects

[0017] According to an embodiment of the present disclosure made as described above, a hot-stamped part may be implemented. However, the scope of the present disclosure is not limited by the effect.

BRIEF DESCRIPTION OF DRAWINGS

[0018]

FIG. 1 shows a transmission electron microscopy (TEM) image of a portion of a hot-stamped part according to an exemplary embodiment of the present disclosure.
FIG. 2 is a load-displacement graph with respect to a nano indentation test of a hot-stamped part according to an exemplary embodiment of the present disclosure.
FIG. 3 is an enlarged view showing a serration behavior of a portion A of FIG. 2.
FIG. 4 is a graph obtained by measuring indentation dynamic strain aging.
FIG. 5 is an enlarged view enlarging a portion B of FIG. 4.
FIG. 6 is a schematic view showing a mechanism of an indentation dynamic strain aging with respect to a lath of a hot-stamped part and dislocation movement in a lath boundary, according to an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION

[0019] The present disclosure may have various modifications thereto and various embodiments, and thus particular embodiments will be illustrated in the drawings and described in detail in a detailed description. Effects and features of the present disclosure, and a method of achieving them will be apparent with reference to the embodiments described in detail in conjunction with the drawings. However, the present disclosure is not limited to the embodiments disclosed below, but may be implemented in various forms.

[0020] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings, and in description with reference to the drawings, the same or corresponding components are given the same reference numerals, and redundant description thereto will be omitted.

[0021] Herein, the terms such as first, second, etc., have been used to distinguish one component from other components, rather than limiting.

[0022] Herein, singular forms include plural forms unless apparently indicated otherwise contextually.

[0023] Herein, the terms "include", "have", or the like, are intended to mean that there are features, or components, described herein, but do not preclude the possibility of adding one or more other features or components.

[0024] Herein, when a portion, such as a film, a region, a component, etc., is present on or above another portion, this case may include not only a case where it is directly on the other portion, but also a case where another film, region, component, etc., is arranged between the portion and the other portion.

[0025] Herein, when a film, a region, a component, etc., are connected, the case may include a case where they are directly connected, or/and a case where they are indirectly connected, having another film, region, and component therebetween. For example, herein, when a film, a region, a component, etc., are electrically connected, the case may include a case where they are directly electrically connected, and/or a case where they are indirectly electrically connected, having another film, region, and component therebetween.

[0026] Herein, "A and/or B" may indicate A, B, or both A and B. "at least one of A and B" may indicate A, B, or both A and B.

[0027] Herein, when a certain embodiment may be implemented otherwise, a particular process order may be performed differently from the order described. For example, two processes described in succession may be performed substantially simultaneously, or may be performed in an order reverse to the order described.

[0028] In the drawings, the size of components may be exaggerated or reduced for convenience of description. For example, the size and thickness of each component shown in the drawings are shown for convenience of description, and thus the present disclosure is not necessarily limited to the illustration.

[0029] FIG. 1 shows a transmission electron microscopy (TEM) image of a portion of a hot-stamped part according to an exemplary embodiment of the present disclosure.

[0030] Referring to FIG. 1, a hot-stamped part may include a base steel sheet. The base steel sheet may be a steel sheet manufactured by performing a hot-rolling process and/or a cold rolling process with respect to a slab cast to include a predetermined content of a predetermined alloy element. In an exemplary embodiment, the base steel sheet may include carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), boron (B), the remainder iron (Fe), and other unavoidable impurities. In an exemplary embodiment, the base steel sheet may further include, as an additive, at least any one of titanium (Ti), niobium (Nb), and vanadium (V). In another embodiment, the base steel sheet may further include a predetermined content of calcium (Ca).

[0031] Carbon (C) may act as an austenite stabilizing element in the base steel sheet. Carbon is a main element that determines the strength and hardness of the base steel sheet, and may be added to secure the tensile strength of the base steel sheet (e.g., a tensile strength of 1,350 MPa or greater) and to secure hardenability properties, after a hot stamping process. Carbon may be included in an amount of about 0.19 wt% to about 0.25 wt% with respect to a total weight of the base steel sheet. When a content of carbon is less than 0.19 wt%, it is difficult to satisfy the mechanical strength of the base steel sheet because a hard phase (martensite, etc.) is difficult to secure. On the other hand, when a content of carbon exceeds 0.25 wt%, brittleness may occur in the base steel sheet or bending performance of the base steel sheet may be reduced.

[0032] Silicon (Si) may act as a ferrite stabilizing element in the base steel sheet. Silicon (Si), which is a solid solution strengthening element, improves the strength of the base steel sheet and improves a concentration of carbon in austenite by suppressing formation of a low-temperature carbide. Silicon is a key element in hot rolling, cold rolling, hot pressing, structure homogenization (perlite, manganese segregation zone control), and fine dispersion of ferrite. Silicon may act as a martensitic strength heterogeneity control element to improve crashworthiness. Silicon may be included in an amount of about 0.1 wt% to about 0.6 wt% with respect to a total weight of the base steel sheet. When a content of silicon is less than 0.1 wt%, the foregoing effect is difficult to obtain, and cementite formation and coarsening may occur in a final hot stamping martensitic structure, and the equalization effect of the base steel sheet is insignificant, and a V-bending angle may not be secured. On the other hand, when a content of silicon exceeds 0.6 wt%, hot rolling and cold rolling loads increase, a hot-rolled red scale becomes excessive, and plating properties of the base steel sheet may be deteriorated.

[0033] Manganese (Mn) may act as an austenite stabilizing element in the base steel sheet. Manganese may be added to increase hardenability and strength in thermal treatment. Manganese may be included in an amount of about 0.8 wt% to about 1.6 wt% with respect to a total weight of the base steel sheet. When a content of manganese is less than 0.8 wt%, a hard phase fraction in a molded article after hot stamping may be insufficient due to insufficient hardenability caused by the insufficient hardenability effect. On the other hand, when a content of manganese exceeds 1.6 wt%, the ductility and toughness may be reduced by manganese segregation or pearlite bands, resulting in degradation of bending performance and causing a heterogeneous micro-structure.

[0034] Phosphorous (P) may be included in an amount of 0 to about 0.03 wt% with respect to a total weight of the base steel sheet to prevent the toughness of the base steel sheet from being reduced. When a content of phosphorous exceeds about 0.03 wt%, an iron phosphide compound is formed, degrading toughness and weldability and causing a crack in the base steel sheet during a manufacturing process.

[0035] Sulfur (S) may be included in an amount of 0 to about 0.015 wt% with respect to a total weight of the base steel sheet. When a content of sulfur exceeds 0.015 wt%, hot workability, weldability, and impact characteristics may be degraded and a surface defect such as a crack, etc., may occur due to generation of a giant inclusion.

[0036] Chrome (Cr) may be added to improve the hardenability and strength of the base steel sheet. Chrome makes it possible to refine grains and secure strength through precipitation hardening. Chrome may be included in an amount of about 0.1 wt% to about 0.6 wt% with respect to a total weight of the base steel sheet. When a content of chrome is less than 0.1 wt%, the precipitation hardening effect is low, and on the other hand, when a content of chrome exceeds 0.6 wt%, Cr-based precipitate and matrix solid solution amount increase, degrading toughness, and cost price increases, increasing production cost.

[0037] Boron (B) may be added to secure hardenability and strength of the base steel sheet by securing a martensitic structure by suppressing the transformation of ferrite, pearlite and bainite. Boron may be segregated in a grain boundary to lower grain boundary energy to increase hardenability, and may have a grain refining effect by increasing an austenite grain growth temperature. Boron may be included in an amount of about 0.001 wt% to about 0.005 wt% with respect to a total weight of the base steel sheet. Boron, when included in the foregoing range, may prevent the occurrence of hard phase intergranular brittleness and secure high toughness and bendability. The hardenability effect may be insufficient when a content of boron is less than 0.001 wt%, and on the other hand, when a content of boron exceeds 0.005 wt%, boron may be easily precipitated in a grain boundary according to a heat treatment condition due to a low solid solubility, degrading hardenability or causing hot embrittlement, and toughness and bendability may be degraded due to occurrence of hard phase intergranular brittleness.

[0038] Meanwhile, fine precipitates may be included in the base steel sheet according to an exemplary embodiment of the present disclosure. An additive constituting some of elements included in the base steel sheet may be a nitride or carbide forming element contributing to formation of fine precipitates.

[0039] More specifically, the additive may include at least any one of titanium (Ti), niobium (Nb), and vanadium (V). Titanium (Ti), niobium (Nb), and vanadium (V) may form fine precipitates in the form of nitrides or carbides, thereby securing the strength of a hot stamped and quenched member. Moreover, they may be contained in an Fe-Mn-based composite oxide, may function as an effective hydrogen trap site for improving the delayed fracture resistance, and may be elements necessary for improving the delayed fracture resistance. The additive may be included in an amount of about 0.1 wt% or less in total with respect to a total weight of the base steel sheet. When a content of the additive exceeds 0.1 wt%, yield strength may excessively increase.

[0040] Titanium (Ti) may be added to strengthen grain refinement and upgrade a material by forming precipitates after hot pressing heat treatment. Moreover, titanium may form a precipitation phase such as TiC and/or TiN, etc., at high temperatures, thereby effectively contributing to austenite grain refinement. Titanium may be included in an amount of about 0.018 wt% to about 0.045 wt% with respect to a total weight of the base steel sheet. Titanium, when included in the content range, may prevent continuous casting defects and precipitate coarsening, easily secure the physical property of a steel material, and prevent a defect such as occurrence of a crack, etc., on a surface of the steel material. On the other hand, when a content of titanium exceeds 0.045 wt%, a precipitate may be coarsened, degrading elongation and bendability.

[0041] Niobium (Nb) and vanadium (V) may be added to increase strength and toughness according to a decrease in a martensite packet size. Each of niobium and vanadium may be included in an amount of about 0.025 wt% to about 0.050 wt% with respect to a total weight of the base steel sheet. Niobium and vanadium, when included in the foregoing range, may have an excellent grain refining effect of the steel material in hot rolling and cold rolling processes, prevent occurrence of a crack in a slab in steelmaking/continuous casting and occurrence of brittleness rupture in a product, and minimize generation of a steelmaking coarse precipitate.

[0042] Calcium (Ca) may be added for inclusion shape control. Calcium may be included at about 0.003 wt% or less with respect to a total weight of the base steel sheet.

[0043] As described above, a hot-stamped part according to an embodiment of the present disclosure may include fine precipitates including a nitride or carbide of at least one of titanium (Ti), niobium (Nb), and vanadium (V) in a base steel sheet. Such fine precipitates may be distributed in the base steel sheet to trap hydrogen. That is, the fine precipitates may provide a trap site for hydrogen introduced inside in or after manufacturing of the hot-stamped part, thereby improving hydrogen embrittlement of the hot-stamped part.

[0044] In an exemplary embodiment, the number of fine precipitates formed in the base steel sheet may be controlled to satisfy a preset range. In an exemplary embodiment, the fine precipitates may be included in the base steel sheet in the number of about 6,000 per unit area (100 μm^2) to about 21,000 per 100 μm^2. In addition, in an exemplary embodiment, an average diameter of the fine precipitates distributed in the base steel sheet may be less than or equal to about 0.0075 μm, and preferably, about 0.004 μm to about 0.0075 μm. The hot-stamped part including the foregoing fine precipitates may have improved bendability and crashworthiness due to excellent V-bending characteristics.

[0045] More specifically, the fine precipitates may be included in the base steel sheet in the number of about 7,500 per unit area (100 μm^2) to about 18,000 per 100 μm^2. In an exemplary embodiment, the average diameter of the fine precipitates distributed in the base steel sheet may be about 0.0068 μm or less. Among such fine precipitates, a rate of fine precipitates having a diameter of about 10 nm or less may be about 63 % or greater and a rate of fine precipitates having a diameter of about 5 nm or less may be about 28 % or greater. Under the above-described condition, the hot-stamped part including the fine precipitates may have not only superior bendability and crashworthiness, but also have improved hydrogen delayed fracture characteristics.

[0046] A diameter of the fine precipitates may have a great influence upon improvement of the hydrogen delayed fracture characteristics. When the number, size, rate, etc., of fine precipitates are formed in the above-described range, tensile strength (e.g., 1350 MPa) required after hot stamping may be secured and formability and bendability may be improved. For example, when the number of fine precipitates per unit area (100 μm^2) is less than 7,500/100 μm^2, the strength of the hot-stamped part may be degraded, and when the number of fine precipitates per unit area exceeds 18,000/100 μm^2, the formability or bendability of the hot-stamped part may be degraded.

[0047] In an exemplary embodiment, the amount of activation hydrogen in the base steel sheet may be about 0.8 wppm or less. The amount of activation hydrogen may mean the amount of hydrogen except for hydrogen trapped in the fine precipitates among hydrogen introduced in the base steel sheet. The amount of activation hydrogen may be measured using a thermal desorption spectroscopy method. More specifically, the amount of hydrogen emitted from a specimen sample below a certain temperature may be measured while a temperature is boosted by heating the specimen sample at a preset heating rate. In this case, hydrogen emitted from the specimen sample below the certain temperature may be understood as activation hydrogen that affects the hydrogen delayed fracture without being trapped among hydrogen introduced into the specimen sample. For example, as a comparative example, when a hot-stamped part includes the amount of activation hydrogen over 0.8 wppm in the base steel sheet, the hydrogen delayed fracture characteristics may be degraded and the hot-stamped part according to the comparative example may be more easily fractured than the hot-stamped part according to the current embodiment in a bending test under the same condition.

[0048] Meanwhile, the base steel sheet according to the current embodiment may include a martensite structure in which a fine structure is distributed. The martensite structure is a result of diffusionless transformation of austenite γ under an initiation temperature Ms of martensite transformation during cooling. A fine structure in the martensite structure may be a diffusionless transformation structure made during rapid cooling within grains called a prior austenite grain boundary (PAGB), and may include a plurality of lath L structures. The plurality of lath L structures may constitute a monomer such as a block or a packet. More specifically, the plurality of lath L structures may form a block, a plurality of blocks may form a packet, and a plurality of packets may form a PAGB.

[0049] As described above, martensite may have a lath L structure in the form of a long and thin rod aligned in a direction in each prior grain of austenite. The plurality of lath L structures may have a property of resisting external strain in a boundary between them, that is, a lath boundary LB. This will be described in detail later.

[0050] Meanwhile, a V-bending angle of the hot-stamped part according to the current embodiment may be 50° or greater. 'V-bending' may be a parameter for evaluating a bending strain property in maximum load sections in strain appearing in bending performance. That is, looking at a tensile strain region during bending in macroscopic and microscopic sizes according to the load-displacement evaluation of a hot-stamped part, when a fine crack occurs and propagates in a local tensile region, the bending performance, called the V-bending angle, may be evaluated.

[0051] As described above, the hot-stamped part according to the exemplary embodiment may include a martensite structure having a plurality of lath L structures, a crack occurring in bending strain may occur when a one-dimensional defect called a dislocation moves through interaction in the martensite structure. It may be understood that in given plastic strain, a higher local strain rate leads to a higher energy absorption degree for plastic strain of martensite, and thus crashworthiness increases.

[0052] In the hot-stamped part according to an exemplary embodiment of the present disclosure, as the martensite structure has the plurality of lath L structures, dynamic strain aging (DSA), i.e., indentation DSA may occur due to a strain rate difference during repeated movement of the dislocation between a lath L and a lath boundary LB in bending strain. The indentation DSA, which is a concept of plastic strain absorbed energy, may mean resistance performance with respect to strain, and thus its resistance performance with respect to strain may be evaluated as being excellent as the indentation DSA phenomenon is frequent.

[0053] In the hot-stamped part according to an exemplary embodiment of the present disclosure, the martensite structure has a plurality of lath L structures in a coarse form, and thus the indentation DSA phenomenon may frequently occur, such that a V-bending angle of 50° or greater may be secured, thereby improving bendability and crashworthiness.

[0054] In an exemplary embodiment, an average interval between the plurality of laths L included in the martensite structure of the hot-stamped part according to the exemplary embodiment may be about 140 nm to about 300 nm. As a comparative example, it is assumed that a hot-stamped part including a base steel sheet out of a composition of the elements described above includes a lath structure. An average interval between lath structures of the hot-stamped part of the comparative example may be greater than the average interval of the lath L structure of the hot-stamped part according to the current embodiment. That is, the hot-stamped part according to the current embodiment may have a coarser lath L structure than the comparative example, and as the lath L structure in the hot-stamped part becomes coarser, the number of indentation DSA may further increase.

[0055] FIG. 2 is a load-displacement graph with respect to a nano indentation test of a hot-stamped part according to an exemplary embodiment of the present disclosure, and FIG. 3 is an enlarged view showing a serration behavior of a portion A of FIG. 2.

[0056] Referring to FIG. 2, a graph of a result of performing a nano indentation test with respect to a hot-stamped part according to an embodiment of the present disclosure is shown. The 'nano indentation test' is a test in which strain of a force with respect to a depth is measured by pressing an indenter perpendicularly against the surface of the hot-stamped part. In FIG. 2, an x-axis indicates a depth to which the indenter is indented and a y-axis indicates a force with respect to an indented depth. For example, while a cube-corner tip (a centerline-to-face angle = 35.3° and an indentation strain rate = 0.22) is used as the indenter in FIG. 2, the present disclosure is not limited thereto and a Berkovich tip (a centerline-to-face angle = 65.3° and an indentation strain rate = 0.072) may be used.

[0057] Referring to FIG. 3 enlarging the portion A of FIG. 2, it may be seen that in indentation and plastic strain occurring in a nano indentation test, serrated strain, i.e., a characteristic behavior called serration is observed. The serration behavior may repeatedly occur at approximately regular intervals, and in FIG. 3, the serration behavior is indicated by a downward arrow (↓).

[0058] The serration behavior may be caused by diffusionless transformation structures in the PAGB included therein in the indentation test of the hot-stamped part. More specifically, the serration behavior in the load-displacement curve as shown in FIG. 2 appears due to interaction between a dislocation and a solute atom diffusing in a material, and may be understood as being caused by a difference in resistance to an external pressure between the plurality of laths distributed in the PAGB and the lath boundary portion formed therebetween. The serration behavior may be recognized as a main evidence of the DSA of FIG. 4, i.e., the indentation DSA phenomenon.

[0059] FIG. 4 is a graph measuring indentation DSA, and FIG. 5 is an enlarged view enlarging a portion B of FIG. 4.

[0060] FIG. 4 is a graph analyzing a nano indentation strain rate ([dh/dt]/h where h indicates an indentation depth and t indicates a unit time) based on the load-displacement curve of FIG. 3.

[0061] In an exemplary embodiment, in the hot-stamped part, with respect to an indentation strain rate for an indentation depth of about 200 nm to about 600 nm observed in a nano indentation test, the number of indentation DSA may be about 26 to about 40. The indentation DSA may be shown as a behavior where an indentation strain rate repeatedly forms a plurality of peaks.

[0062] The number of indentation DSA may be calculated based on a peak passing a reference line C as a center. That is, the number of indentation DSA may be calculated based on a peak formed passing through the reference line

C without calculating a peak formed above or under the reference line C. The reference line C may be a line that assumes that the indentation DSA caused by the lath and the lath boundary structure is removed in indentation strain rate measurement.

[0063] Referring to the indentation strain rate graph of FIG. 5, it may be seen that when the indentation depth gradually increases, the number and size of indentation DSA gradually decrease. This is because as the indentation depth gradually increases, the indentation physical properties of the prior austenite grain are mixed and thus the indentation DSA rarely appears. Referring to FIG. 4, it may be seen that at an indentation depth of 600 nm or greater, the indentation DSA substantially rarely appears. In the graph of FIG. 4, an indentation depth of 700 nm or greater is not measured, but a curve in which DSA is removed from a corresponding section may be obtained by continuously measuring an indentation strain rate with respect to an indentation depth of 700 nm or greater. The reference line C may be derived by reversely estimating an indentation strain rate curve at an indentation depth where the indentation DSA is removed.

[0064] As described above, the number of indentation DSA of the hot-stamped part according to the current embodiment may be 26 to 40, which may be based on measurement in a section of an indentation depth of about 200 nm to about 600 nm. While measurement is performed at an indentation depth of 0 nm to about 700 nm in FIG. 4, the accuracy of the indentation strain rate is low due to a blunt indenter at an indentation depth below about 200 nm and indentation physical properties of the prior austenite grain are mixed at an indentation depth above about 600 nm, making it difficult to evaluate DSA.

[0065] As shown in FIG. 4, the indentation strain rate gradually decreases secondarily according to the indentation depth when viewed macroscopically. In this case, the indentation DSA may appear as a behavior where the indentation strain rate repeatedly forms the plurality of peaks. To observe this in detail, in FIG. 5, the indentation strain rate with respect to the indentation depth of about 350 nm to about 400 nm of FIG. 4 is shown enlarged.

[0066] Referring to FIG. 5, the indentation strain rate may appear in a form where a rise section and a drop section are repeated. A section a may mean a section where an indentation strain rate increases in an indentation test, absorbing a resistance. That is, the section a may be understood as a section where a dislocation glides in a lath distributed in a PAGB in dislocation movement in a tension-generated portion during bending strain. As such, when the dislocation moves in the lath, the hot-stamped part shows a property of absorbing external resistance, which may appear as a section where the indentation strain rate rises as shown in FIG. 5. The dislocation rises to a lath boundary portion and at the moment when the dislocation passes the lath boundary, the indentation strain rate drops as in the section b, which may be interpreted as a phenomenon occurring due to interaction with fine precipitates distributed in the lath boundary.

[0067] FIG. 6 is a schematic view showing a mechanism of an indentation DSA with respect to dislocation movement in bending strain of a hot-stamped part, according to an embodiment of the present disclosure.

[0068] Referring to FIG. 6, the lath L distributed in the PAGB and the lath boundary LB in a tension-generated portion in bending strain are shown, schematically showing movement of a dislocation according to the indentation DSA of FIG. 5. As described above, in bending strain, the dislocation may move along an adjacent lath L. An arrow of FIG. 6 indicates a moving direction of the dislocation.

[0069] As such, it may be analyzed that in movement of the dislocation, an indentation strain rate differs with energy absorption degrees in the lath L and in the lath boundary LB. Referring to FIGS. 5 and 6 together, a case where the dislocation moves along an arrow of FIG. 6 in the lath L may correspond to the section a of FIG. 5. That is, when the dislocation moves in the lath L, the indentation strain rate may rise. The indentation strain rate rises until the dislocation is adjacent to the lath boundary LB, and drops at the moment when the dislocation passes the lath boundary LB, which may correspond to the section b of FIG. 5. As such, the indentation DSA as shown in FIG. 5 may occur due to interaction between the dislocation and the lath boundary LB in movement of the dislocation. As described above, the fine precipitates are distributed in the lath boundary LB, delaying the strain, and the strain rate rise and drop repeatedly occur during passage of the plurality of laths L, causing the indentation DSA.

[0070] The hot-stamped part according to an embodiment of the present disclosure may control the fine precipitates included in the base steel plate to reduce the average interval between the plurality of laths such that the indentation DSA phenomenon more frequently occurs when the dislocation glides in bending strain. In this way, as the indentation DSA phenomenon increases through coarsening of a lath structure, the hot-stamped part according to an exemplary embodiment of the present disclosure may secure a V-bending angle of 50° or greater without rupture in bending strain.

[0071] Hereinafter, the present disclosure will be described in more detail through embodiments and comparative examples. However, the following embodiments and comparative examples are for describing the present disclosure in more detail, and the scope of the present disclosure is not limited by the following embodiments and comparative examples. The following embodiments and comparative examples may be appropriately modified and changed by those of ordinary skill in the art within the scope of the present disclosure.

[0072] The hot-stamped part according to an exemplary embodiment of the present disclosure may be formed through a hot-stamping process on a base steel sheet having a composition as shown in Table 1 below.

Table 1

Constitution (wt%)							
C	Si	Mn	P	S	Cr	B	Additive
0.19 ~ 0.25	0.1 -0.6	0.8 ~ 1.6	0.03 or less	0.015 or less	0.1 ~ 0.6	0.001 ~ 0.005	0.1 or less

[0073] As described above, the hot-stamped part according to an exemplary embodiment of the present disclosure may include fine precipitates including a nitride and/or a carbide of an additive in a base steel sheet, in which the fine precipitates in the hot-stamped part may be included per unit area (100 μm^2) in 6,000/100 μm^2 to 21,000/100 μm^2 in the base steel sheet. In an exemplary embodiment, the average diameter of the fine precipitates distributed in the base steel sheet may be about 0.004 μm to about 0.0075 μm. The hot-stamped part satisfying the foregoing condition may have a V-bending angle of 50° or greater. Table 2 shows values measured by quantifying the precipitation behavior of the fine precipitates and the number of indentation DSA and a V-bending angle of the exemplary embodiments of the present disclosure and the comparative examples with respect to a titanium content.

Table 2

Classification	Ti (wt. %)	Lath Interval (nm) Average	TiC-based Precipitation Density (/100 μm^2) Total Number	Precipitate Size (μm) Average	Indentation Dynamic Strain Aging (Number)	V-Bending (°)
Embodiment 1	0.018	300	6,032	0.0040	26	50
Embodiment 2	0.025	200	9,954	0.0051	29	53
Embodiment 3	0.030	180	14,266	0.0054	32	55
Embodiment 4	0.042	160	18,920	0.0060	37	56
Embodiment 5	0.045	140	20,990	0.0075	40	55
Embodiment 6	0.030	190	14,443	0.0053	33	54
Embodiment 7	0.035	168	16,599	0.0061	35	56
Comparative Example 1	0.047	135	21,063	0.0078	24	43
Comparative Example 2	0.017	320	5,911	0.0035	25	45

[0074] In Table 2, Embodiment 1 to Embodiment 7 satisfy a precipitation behavior condition of fine precipitates and a formation condition of a plurality of laths with respect to a titanium content as described above. More specifically, in Embodiment 1 to Embodiment 7, titanium may be included in an amount of about 0.018 wt% to about 0.045 wt%, and a corresponding average interval of a plurality of laths may be about 140 nm to about 300 nm, and fine precipitates including titanium, e.g., the number of titanium carbides (TiC) per unit area may be about 6,000/100 μm^2 to about 21,000/100 μm^2, and an average diameter of the total fine precipitates may be about 0.004 μm to about 0.0075 μm. In this case, the number of indentation DSA satisfies a condition of 26 to 40. As such, it may be seen that Embodiment 1 to Embodiment 7 satisfying the precipitation behavior condition and the formation condition of the plurality of laths of the present disclosure may secure a V-bending angle of 50° or greater, such that tensile strength and bendability are improved. On the other hand, it may be seen that Comparative Example 1 and Comparative Example 2 fail to satisfy at least some of the precipitation behavior condition and the formation condition of the plurality of laths described above, such that tensile strength and bendability are lower than in Embodiment 1 to Embodiment 7.

[0075] In Comparative Example 1, as a titanium content is 0.047 wt%, the size of the fine precipitates is coarsened, such that the average interval between the plurality of laths is reduced to about 135 nm and the number of indentation DSA is 24, failing to satisfy the foregoing conditions. Thus, a V-bending angle of Comparative Example 1 is merely 43°.

[0076] In Comparative Example 2, as a titanium content is 0.017 wt%, the size and density of the fine precipitates decrease, such that the average interval between the plurality of laths increases to about 320 nm and the number of indentation DSA is 25, failing to satisfy the foregoing conditions. Thus, a V-bending angle of Comparative Example 2 is merely 45°.

[0077] More specifically, the fine precipitates in the hot-stamped part according to an exemplary embodiment of the present disclosure may be included per unit area (100 μm^2) in 7,500/100 μm^2 to 18,000/100 μm^2 in the base steel sheet. In an exemplary embodiment, the average diameter of the fine precipitates distributed in the base steel sheet may be about 0.0068 μm or less. Among such fine precipitates, a rate of fine precipitates having a diameter of about 0.01 μm or less may be about 63 % or greater and a rate of fine precipitates having a diameter of about 0.005 μm or less may be about 28 % or greater. In an exemplary embodiment, the amount of activation hydrogen in the base steel sheet may be about 0.8 wppm or less. The hot-stamped part having the foregoing characteristics has superior bendability and has improved hydrogen embrittlement resistance.

[0078] Table 3 shows values measured by quantifying the precipitation behavior of the fine precipitates of the embodiments according to exemplary embodiments of the present disclosure and the comparative examples.

[0079] The precipitation behavior of the fine precipitates may be measured using a method of analyzing a TEM image. More specifically, TEM images for random regions as many as a preset number may be obtained for a specimen sample. The fine precipitates may be extracted from the obtained images through an image analysis program, etc., and the number of fine precipitates, an average distance between the fine precipitates, a diameter of the fine precipitates, etc., may be measured for the extracted fine precipitates.

[0080] In an exemplary embodiment, for precipitation behavior measurement of the fine precipitates, a replication method may be applied to the specimen sample to be measured, as pretreatment. For example, a one-step replica method, a two-step replica method, an extraction replica method, etc., may be applied, without being limited thereto.

[0081] In another exemplary example, in measurement of the diameter of the fine precipitate, by considering non-uniformity of the form of the fine precipitate, the shape of the fine precipitate may be converted into a circle to calculate the diameter of the fine precipitate. More specifically, an area of the fine precipitate extracted using a unit pixel having a specific area may be measured, and the fine precipitate may be converted into a circle having the same area as the measured area, thereby calculating the diameter of the fine precipitate.

Table 3

Speci men Sampl e	Total Fine Precipitate Number (No./100 μm^2)	Total Fine Precipitate Average Diameter (μm)	Diameter of 10 nm or less Rate of Fine Precipitate (%)	Diameter of 5 nm or less Rate of Fine Precipitate (%)	Activation Hydrogen Amount (Wppm)
A	7,512	0.0067	63.2	28.0	0.779
B	7,520	0.0040	92.4	37.7	0.764
C	8,768	0.0059	62.9	29.0	0.764
D	12,973	0.0044	93.5	62.9	0.771
E	16,316	0.0041	95.9	75.1	0.759
F	17,990	0.0057	63.1	28.2	0.752
G	17,980	0.0044	80.9	28.1	0.767
H	8,944	0.0047	71.7	41.4	0.751
I	13,173	0.0044	98.9	82.8	0.714
J	11,796	0.0068	84.7	60.4	0.739
K	14,612	0.0070	88.7	30.9	0.891
L	16,520	0.0057	62.8	26.2	0.878
M	7,318	0.0058	68.2	27.8	0.865
N	16,600	0.0061	96.1	27.9	0.859

[0082] In Table 3, the precipitation behavior (the number of total fine precipitates per unit area, the average diameter of the fine precipitates, a rate of the fine precipitates having a diameter of about 10 nm or less, an activation hydrogen amount) of the fine precipitates are measured for Specimen Samples A to N. Specimen Samples A to J of Table 3 are specimen samples of the hot-stamped part manufactured using the base steel sheet satisfying the above-described content condition (see [Table 1]), as embodiments of the present disclosure. That is, Specimen Samples A to J satisfy the above-described precipitation behavior conditions of the fine precipitates. More specifically, in Specimen samples A to J, the fine precipitates are formed in 7,500/100 μm^2 to 18,000/100 μm^2 in the steel sheet, the average diameter of the total fine precipitates is about 0.0068 μm or less, 63 % or greater of fine precipitates formed in the steel sheet have a diameter of about 10 nm or less, and 28 % or greater satisfy a diameter of 5 nm or less. It may be seen that for Specimen Samples A to J satisfying the precipitation behavior condition of the present disclosure, hydrogen delayed fracture characteristics are improved as a condition of the activation hydrogen amount being 0.8 wppm or less is satisfied.

[0083] On the other hand, Specimen Samples K to N fail to satisfy at least some of the above-described precipitation behavior conditions of the fine precipitates, and it may be seen than the tensile strength, bendability, and/or hydrogen delayed fracture characteristics thereof are less than those of Specimen Samples A to J.

[0084] For Specimen Sample K, the average diameter of the total specimen samples is about 0.0070 μm. This is less than a lower limit of the average diameter of the total fine precipitates. Thus, the activation hydrogen amount of Specimen Sample K is relatively high as 0.891 wppm.

[0085] For Specimen Sample L, a rate of fine precipitates having a diameter of 10 nm or less is measured as about 62.8 %. Thus, the activation hydrogen amount of Specimen Sample L is relatively high as 0.878 wppm.

[0086] For Specimen sample M and Specimen Sample N, rates of the fine precipitates having a diameter of about 5 nm or less are respectively measured as about 27.8 % and about 27.9 %. Thus, it may be seen that the activation hydrogen amounts of Specimen Sample M and Specimen Sample N are relatively high as about 0.865 wppm and about 0.859 wppm.

[0087] When the precipitation behavior condition of the present disclosure fails to be satisfied as in Specimen Sample K to Specimen Sample N, relatively much hydrogen is trapped in one fine precipitate during a hot-stamping process, or trapped hydrogen elements are locally concentrated and coupled to one another to form a hydrogen molecule H_2 to generate an internal pressure, such that the hydrogen delayed fracture characteristics of a hot-stamped product are reduced.

[0088] On the other hand, when the precipitation behavior condition of the present disclosure is satisfied as in Specimen Sample A to Specimen Sample J, the number of hydrogen atoms trapped in one fine precipitate may be relatively small or the trapped hydrogen atoms may be relatively uniformly distributed during a hot-stamping process. Thus, generation of an internal pressure due to a hydrogen molecule formed by the trapped hydrogen atoms may be reduced, and thus the hydrogen delayed fracture characteristics of the hot-stamped product may be improved.

[0089] As a result, it may be seen that as the hot-stamped part to which the above-described content condition of the present disclosure is applied satisfies the precipitation behavior condition of the above-described fine precipitates after hot stamping, the hydrogen delayed fracture characteristics are improved.

[0090] Although the present disclosure has been described with reference to an example shown in the drawings, it will be understood by those of ordinary skill in the art that various modifications and equivalent other examples may be made from the shown example. Accordingly, the true technical scope of the present disclosure should be defined by the technical spirit of the appended claims.

Claims

1. A hot-stamped part comprising a base steel sheet, the base steel sheet comprising an amount of about 0.19 to about 0.25 wt% of carbon (C), an amount of about 0.1 to about 0.6 wt% of silicon (Si), an amount of about 0.8 to about 1.6 wt% of manganese (Mn), an amount of about 0.03 wt% or less of phosphorus (P), an amount of about 0.015 wt% or less of sulfur (S), an amount of about 0.1 to about 0.6 wt% of chromium (Cr), an amount of about 0.001 to about 0.005 wt% of boron (B), an amount of about 0.1 wt% or less of an additive, remaining iron (Fe), and other unavoidable impurities, wherein in an indentation strain rate with respect to an indentation depth of about 200 nm to about 600 nm observed in a nano indentation test, a number of indentation dynamic strain aging (DSA) is about 26 to about 40.

2. The hot-stamped part of claim 1, wherein the base steel sheet comprises a martensite structure in which a plurality of lath structures are distributed.

3. The hot-stamped part of claim 2, wherein an average interval between a plurality of laths is about 140 nm to about 300 nm.

4. The hot-stamped part of claim 1, further comprising fine precipitates distributed in the base steel sheet,
wherein the fine precipitates comprise a nitride or a carbide of at least any one of titanium (Ti), niobium (Nb), and vanadium (V).

5. The hot-stamped part of claim 4, wherein a number of the fine precipitates distributed per unit area (100 μm^2) is about 7,500 to about 18,000.

6. The hot-stamped part of claim 4, wherein an average diameter of the fine precipitates is about 0.0068 μm or less.

7. The hot-stamped part of claim 4, wherein a rate of fine precipitates having a diameter of about 0.01 μm or less among the fine precipitates is about 63 % or greater.

8. The hot-stamped part of claim 4, wherein a rate of fine precipitates having a diameter of about 0.005 μm or less among the fine precipitates is about 28 % or greater.

9. The hot-stamped part of claim 1, wherein a V-bending angle of the hot-stamped part is equal to or greater than about 50°.

10. The hot-stamped part of claim 1, wherein a tensile strength of the hot-stamped part is equal to or greater than about 1350 MPa.

11. The hot-stamped part of claim 1, wherein an amount of activation hydrogen of the hot-stamped part is about 0.8 wppm or less.

FIG. 1

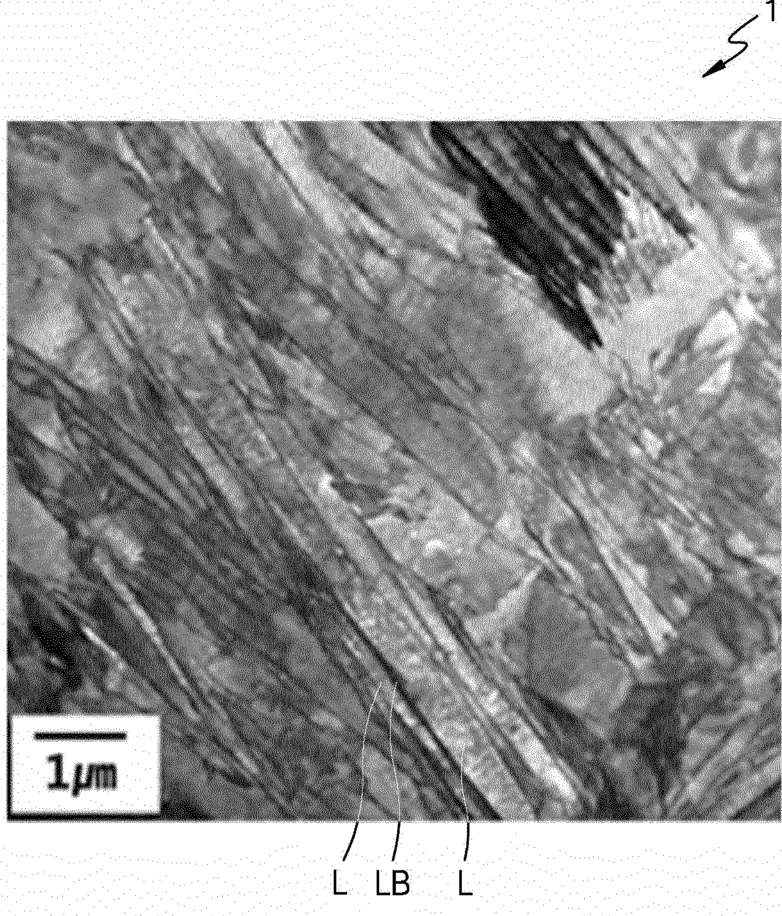
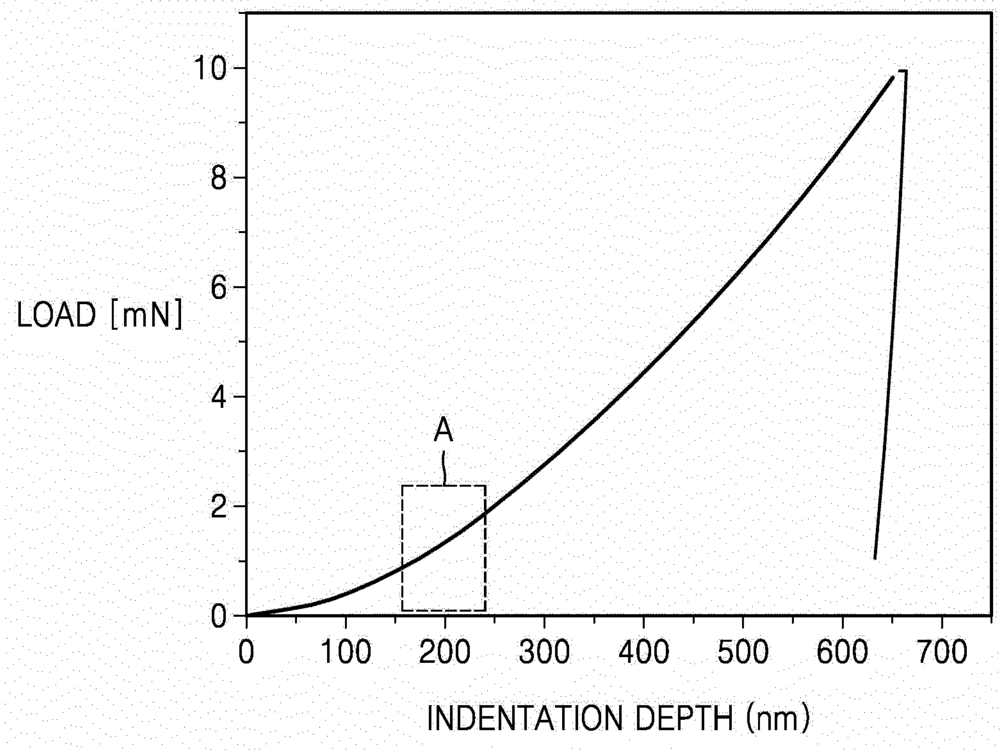


FIG. 2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10
8
6
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A
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500
600
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INDENTATION DEPTH (nm)

FIG. 3

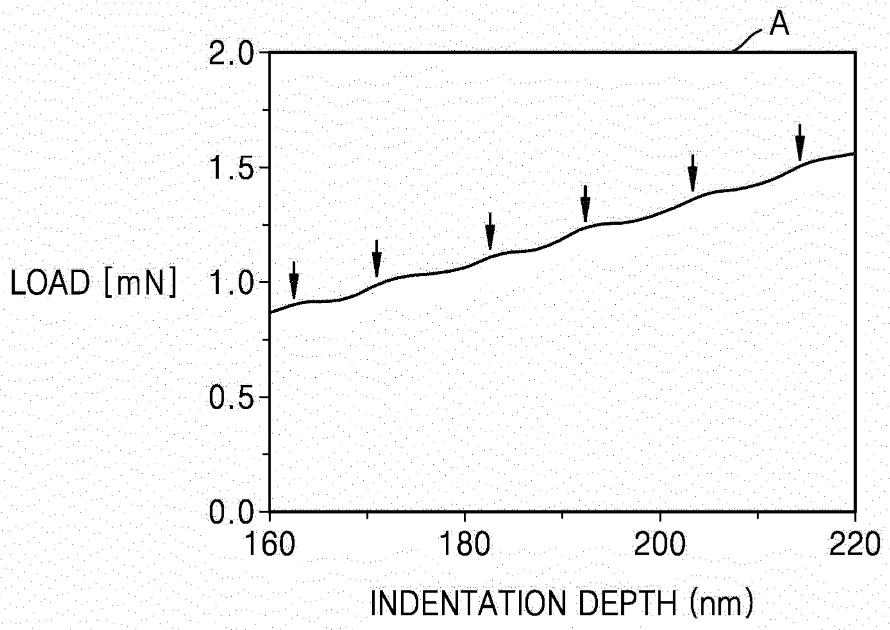
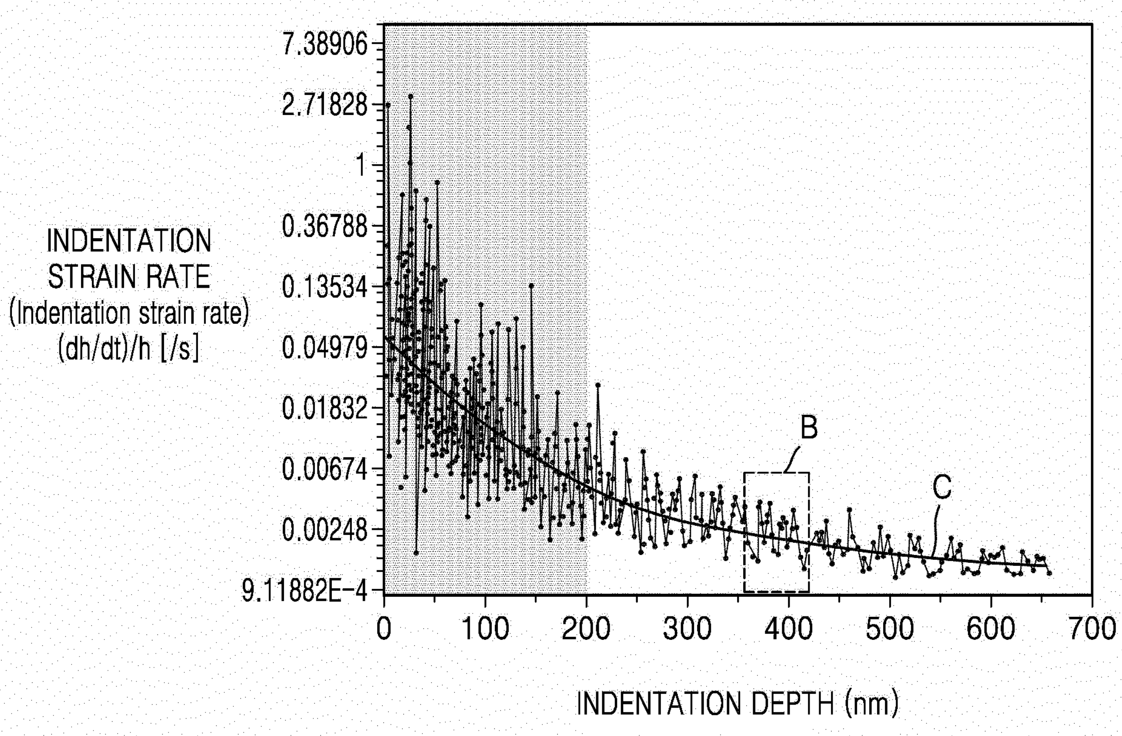


FIG. 4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0.13534
0.04979
0.01832
0.00674
0.00248
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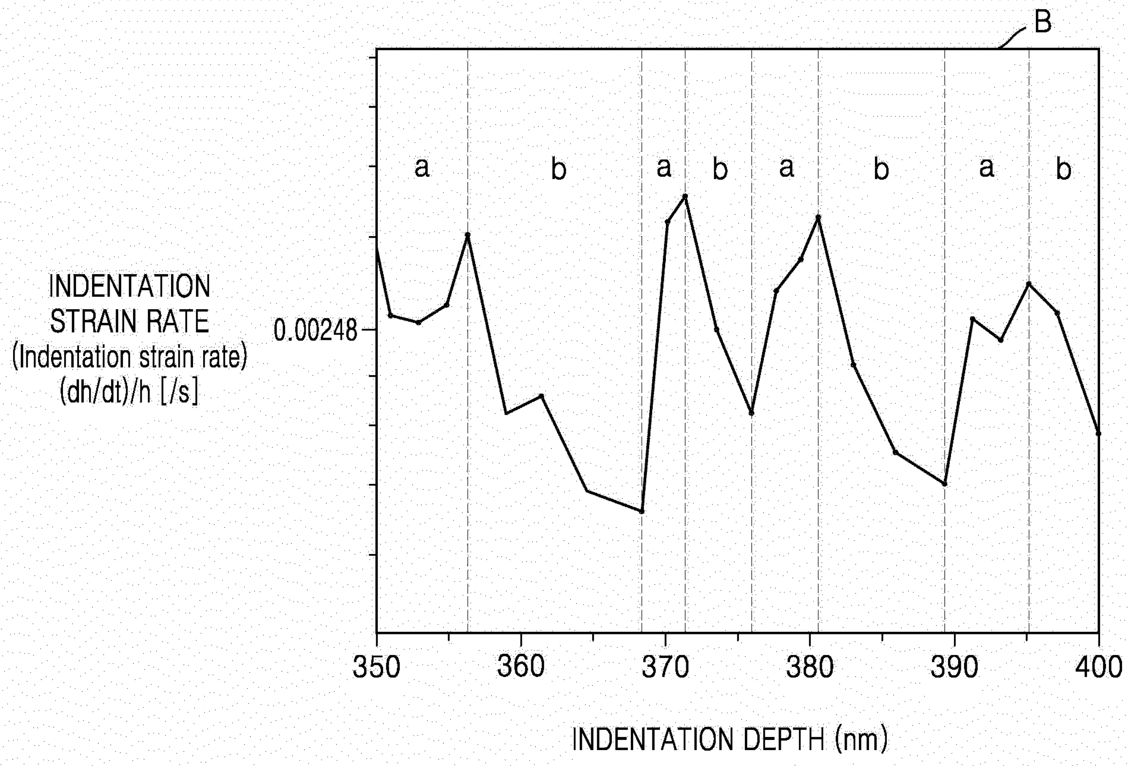
100
200
300
400
500
600
700
INDENTATION DEPTH (nm)
B
C

FIG. 5


B
a
b
a
b
a
b
a
b
INDENTATION
STRAIN RATE
(Indentation strain rate)
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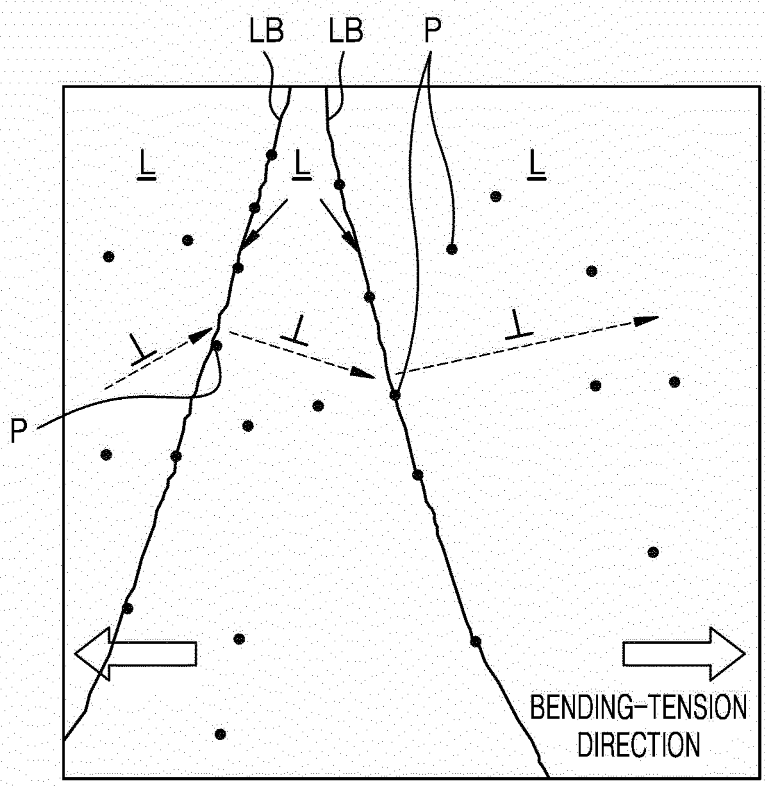
360
370
380
390
400
INDENTATION DEPTH (nm)

FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2021/018545

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/32**(2006.01)i; **B21D 22/02**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/38(2006.01); B21D 22/02(2006.01); B21D 22/20(2006.01); C22C 38/00(2006.01); C22C 38/14(2006.01); C22C 38/46(2006.01); C22C 38/58(2006.01); C23C 28/00(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 핫 스탬핑(hot stamping), 압입 동적 변형 시효(indentation dynamic strain aging), 마르텐사이트(martensite), 래스(lath), 석출물(precipitate)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-150612 A (NIPPON STEEL CORP.) 08 July 2010 (2010-07-08) See paragraph [0014] and claims 1-2.	1-11
A	KR 10-2020-0036248 A (HYUNDAI STEEL COMPANY) 07 April 2020 (2020-04-07) See paragraph [0015] and claim 2.	1-11
A	KR 10-2020-0004364 A (JFE STEEL CORPORATION) 13 January 2020 (2020-01-13) See paragraph [0047] and claims 1-2.	1-11
A	JP 2015-094024 A (NIPPON STEEL & SUMITOMO METAL) 18 May 2015 (2015-05-18) See claim 5.	1-11
A	US 2019-0226064 A1 (FORD GLOBAL TECHNOLOGIES, L.L.C.) 25 July 2019 (2019-07-25) See claims 1 and 5.	1-11

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 2022	**23 March 2022**

Name and mailing address of the ISA/KR	Authorized officer
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Form PCT/ISA/210 (second sheet) (July 2019)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2021/018545

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2010-150612 A	08 July 2010	JP 5257062 B2	07 August 2013
KR 10-2020-0036248 A	07 April 2020	KR 10-2110679 B1	13 May 2020
KR 10-2020-0004364 A	13 January 2020	CN 110799660 A	14 February 2020
		CN 110799660 B	14 May 2021
		EP 3647445 A1	06 May 2020
		EP 3647445 B1	28 April 2021
		JP 6540909 B2	10 July 2019
		JP WO2019-003543 A1	03 January 2019
		KR 10-2296362 B1	31 August 2021
		MX 2019015392 A	20 February 2020
		US 11085101 B2	10 August 2021
		US 2020-0131596 A1	30 April 2020
		WO 2019-003451 A1	03 January 2019
JP 2015-094024 A	18 May 2015	JP 6225654 B2	08 November 2017
US 2019-0226064 A1	25 July 2019	CN 110066961 A	30 July 2019
		DE 102019101546 A1	25 July 2019

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- KR 1020180095757 **[0003]**