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(71) Applicant: **Nippon Steel & Sumitomo Metal Corporation**
Tokyo 100-8071 (JP)

(72) Inventors:
• **TANAHASHI, Hiroyuki**
Tokyo 100-8071 (JP)
• **MAKI, Jun**
Tokyo 100-8071 (JP)

(74) Representative: **Vossius & Partner**
Siebertstrasse 4
81675 München (DE)

(54) **STEEL SHEET FOR HOT-STAMPED MEMBER AND PROCESS FOR PRODUCING SAME**

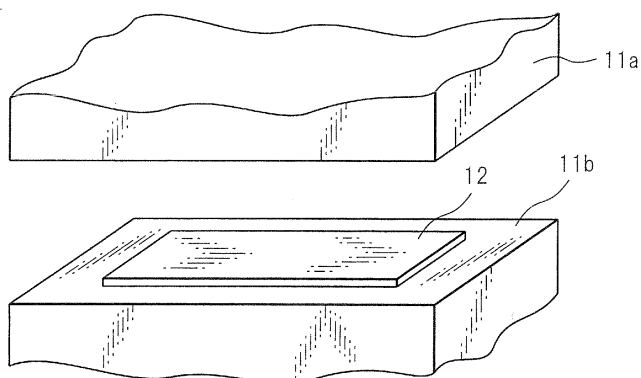
(57) A steel sheet for obtaining a member which is excellent in fatigue characteristics equal to ordinary high strength steel sheet of the same strength even if applying the hot stamping process and a method of production of the same are provided.

Steel sheet for a hot stamped member which includes composition which contains, by mass%, C: 0.15 to 0.35%, Si: 0.01 to 1.0%, Mn: 0.3 to 2.3%, Al: 0.01 to 0.5%, and a balance of Fe and unavoidable impurities, and limit the impurities to P: 0.03% or less, S: 0.02% or

less, and N: 0.1% or less, wherein that a standard error of Vicker's hardness at a position of 20 μm from the steel sheet surface in the sheet thickness direction is 20 or less.

This steel sheet is produced by a recrystallization-annealing step of a first stage of heating a cold rolled steel sheet, which is obtained by hot rolling steel containing the above composition and then cold rolling it, by an average heating rate of 8 to 25°C/sec from room temperature to 600 to 700°C, then a second stage of heating by an average heating rate of 1 to 7°C/sec to 720 to 820°C.

Fig.1



Description

Technical Field

5 **[0001]** The present invention relates to steel sheet for a hot stamped member which is suitable for the hot stamping method, one of the shaping methods giving a high strength member, and a method of production of the same.

Background Art

10 **[0002]** In the field of automobiles, construction machinery, etc., vigorous efforts are being made to reduce weight by use of high strength materials. For example, in automobiles, the amount of use of high strength steel sheet has been steadily increasing for the purpose of cancelling out the increase in vehicle weight accompanying the improvements in impact safety and performance and furthermore improving fuel efficiency to reduce the amount of emission of carbon dioxide.

15 **[0003]** In the trend toward expanded use of such high strength steel sheet, the biggest problem, unavoidable when raising the strength of steel sheet, is the rise of the phenomenon called "degradation of the shape fixability". This phenomenon is the general term for loss of ease of obtaining a target shape due to the increase in the amount of springback after shaping accompanying higher strength. To solve this problem, working steps which were unnecessary with low strength materials (materials with shape fixabilities which are excellent or not a problem) (for example, restriking) have been performed or the product shapes have been changed.

20 **[0004]** As one method for dealing with this situation, the hot shaping method called the "hot stamping method" has come under attention. This heats a steel sheet (worked material) to a predetermined temperature (generally, the temperature resulting in an austenite phase) to lower the strength (that is, facilitate shaping), then shapes it by a die of a lower temperature than the worked material (for example room temperature) to thereby easily impart a shape and simultaneously utilize the temperature between the two for rapid cooling heat treatment (quenching) so as to secure the strength of the shaped product.

25 **[0005]** Several arts relating to steel sheet suitable for such a hot stamping method and method of shaping the same have been reported.

30 **[0006]** PLT 1 shows steel sheet obtained by controlling the amounts of elements which the steel sheet contains and the relationship among the amounts of the elements to predetermined ranges so as to give a member which is excellent in impact characteristics and delayed fracture characteristic after hot shaping (synonymous with hot stamping).

35 **[0007]** PLT 2, in the same way as the above, discloses a method comprising making the amounts of elements which the steel sheet contains and the relationship among the amounts of the elements to predetermined ranges and heating before shaping the steel sheet in a nitriding atmosphere or a carburizing atmosphere so as to obtain a high strength part.

40 **[0008]** PLT 3 describes means for prescribing the composition and microstructure of steel sheet and limiting the heating conditions and shaping conditions so as to obtain hot pressed parts with a high productivity.

45 **[0009]** Recently, the hot stamping method has become widely recognized for its usefulness. Members for which its application has been studied have become much more diverse. Among these, for example, there are parts, such as underbody parts of automobiles, where not only the strength of the parts, but also the fatigue characteristic is an important, necessary characteristic.

50 **[0010]** The fatigue characteristic of steel sheet is improved together with the static strength, so steel sheet (product) made high in strength by the hot stamping method also can be expected to exhibit a commensurate fatigue characteristic, if compared with steel sheet of the same strength not using the hot stamping method (high strength steel sheet produced by controlling the composition or method of production of the strength steel sheet, below, called "ordinary high strength steel sheet"), it became clear that depending on the production conditions, the fatigue characteristics of the former were inferior to the latter.

55 **[0011]** Studied in detail, it was discovered that compared with the deviation in hardness of the surfacemost part of "ordinary high strength steel sheet", the deviation in hardness of the surfacemost part of steel sheet (product) raised in strength by using the hot stamping method is larger. It was concluded that this deviation in hardness might be related to the fatigue characteristic.

60 **[0012]** The relationship between the deviation in hardness and the fatigue characteristic is not necessarily clear, but in a high strength member which is produced by the hot stamping method (for example, a tensile strength of 1500 MPa or more), the effect of the notch sensitivity on the fatigue characteristic is extremely large, so it is guessed that this deviation in hardness might be an indicator comparable to the flatness of a surface layer.

65 **[0013]** Therefore, the inventors studied the art for reducing as much as possible the deviation in hardness after hot stamping and as a result discovered that the deviation in surface layer hardness of the steel sheet before hot stamping has an impact. No literature has been found which studies steel sheet for hot stamping use from such a perspective.

70 **[0014]** PLT 1 discusses steel sheet for hot shaping use where all of Ni, Cu, and Sn are essential, wherein the impact

characteristics and the delayed fracture characteristic are improved, but does not allude to the fatigue characteristic or the deviation in surface layer hardness before hot stamping.

[0015] PLT 2 relates to the art of heating in a carburizing atmosphere so as to raise the strength of a shaped part, but does not allude to the fatigue characteristic or the deviation in surface layer hardness before hot stamping. Heating in a carburizing atmosphere is essential. Compared with heating in the air, the production costs rise. Further, when using carbon monoxide as the source of carbon, there is a concern that tremendous costs would be required for securing the safety of operations. It is believed that this art is not easily workable.

[0016] PLT 3 also does not allude to the fatigue characteristic and the deviation in surface layer hardness before hot stamping.

[0017] As opposed to this, as art for obtaining steel sheet for hot stamping use which has a fatigue characteristic of the same extent as "ordinary high strength steel sheet", there is PLT 4. Further, while as art inherent to the case of use of steel sheet which has been galvanized, PLT 5 is known as art for improving the fatigue characteristic of a member which is produced by the hot stamping method.

[0018] PLT 4 discloses to make fine particles which contain Ce oxides disperse slight inward from the steel sheet surface so as to improve the fatigue characteristic after hot stamping, but advanced steelmaking art is required, so there is the problem that even a person skilled in the art would not necessarily find it easy to work it.

[0019] The art of PLT 5 relates to facilities for hot stamping technology. There is the problem that without new capital investment, even a person skilled in the art could not enjoy its benefits.

In this way, steel sheet for hot stamping use for obtaining steel sheet (product) made high in strength by hot stamping, which enables fatigue characteristics of the same extent as "ordinary high strength steel sheet" of the same strength to be secured relatively easily, has been sought, but no art which solves this problem has been found.

Citations List

Patent Literature

[0020]

PLT 1: Japanese Patent Publication No. 2005-139485A

PLT 2: Japanese Patent Publication No. 2005-200670A

PLT 3: Japanese Patent Publication No. 2005-205477A

PLT 4: Japanese Patent Publication No. 2007-247001A

PLT 5: Japanese Patent Publication No. 2007-182608A

Summary of Invention

Technical Problem

[0021] The present invention, in view of the above situation, has as its object the provision of steel sheet for a hot stamped member which enables the production of a product of high strength steel sheet which has an excellent fatigue characteristic of the same extent as high strength steel sheet which is produced by controlling the composition of the steel sheet or method of production ("ordinary high strength steel sheet") when producing a product by applying the hot stamping method to steel sheet and of a method of production of the same. Solution to Problem

[0022] The inventors engaged in intensive research to solve this problem. As a result, they discovered that making the deviation in hardness near the surface layer of steel sheet before hot stamping within a predetermined range is extremely effective for improving the fatigue characteristic of the steel sheet after hot stamping (product). They discovered that such steel sheet can be obtained by controlling the conditions when recrystallization-annealing the cold rolled steel sheet, conducted repeated tests, and thereby completed the present invention.

[0023] The gist of the invention is as follows:

(1) Steel sheet for a hot stamped member which includes composition which contains, by mass%,

C: 0.15 to 0.35%,

Si: 0.01 to 1.0%,

Mn: 0.3 to 2.3%,

Al: 0.01 to 0.5%, and

a balance of Fe and unavoidable impurities, and limit the impurities to

P: 0.03% or less,

S: 0.02% or less, and

N: 0.1% or less,

wherein a standard deviation of Vicker's hardness at a position of 20 μm from the steel sheet surface in the sheet thickness direction is 20 or less.

(2) The steel sheet for a hot stamped member as set forth in (1) which further contains, by mass%, one or more of elements selected from

Cr: 0.01 to 2.0%,

Ti: 0.001 to 0.5%,

Nb: 0.001 to 0.5%

B: 0.0005 to 0.01%,

Mo: 0.01 to 1.0%

W: 0.01 to 0.5%,

V: 0.01 to 0.5%,

Cu: 0.01 to 1.0%, and

Ni: 0.01 to 5.0%.

(3) The steel sheet for a hot stamped member as set forth in (1) or (2) which has on the surface of the steel sheet one of a 5 μm to 50 μm thick Al plating layer, a 5 μm to 30 μm thick galvanized layer, or a 5 μm to 45 μm thick Zn-Fe alloy layer.

(4) A method of production of steel sheet for a hot stamped member comprising recrystallization-annealing cold rolled steel sheet which includes composition which contains, by mass%,

C: 0.15 to 0.35%,

Si: 0.01 to 1.0%,

Mn: 0.3 to 2.3%,

Al: 0.01 to 0.5%, and

a balance of Fe and unavoidable impurities, and limit the impurities to

P: 0.03% or less,

S: 0.02% or less, and

N: 0.1% or less,

in which step, including

a first stage of heating by an average heating rate of 8 to 25°C/sec from room temperature to a temperature M (°C) and

then a second stage of heating by an average heating rate of 1 to 7°C/sec to a temperature S (°C),

wherein the temperature M (°C) is 600 to 700 (°C) and the temperature S (°C) is 720 to 820 (°C).

(5) The method of production of steel sheet for a hot stamped member as set forth in (4) wherein the steel further contains, by mass%, one or more of Cr: 0.01 to 2.0%,

Ti: 0.001 to 0.5%,

Nb: 0.001 to 0.5%

B: 0.0005 to 0.01%,

Mo: 0.01 to 1.0%

W: 0.01 to 0.5%,

V: 0.01 to 0.5%,

Cu: 0.01 to 1.0%, and

Ni: 0.01 to 5.0%.

(6) The method of production of steel sheet for a hot stamped member as set forth in (4) or (5) wherein a hot rolling rate in the hot rolling step is 60 to 90%, while a cold rolling rate of the cold rolling step is 30 to 90%.

(7) The method of production of steel sheet for a hot stamped member as set forth in any one of (4) to (6) which further includes, after the recrystallization-annealing step, a step of dipping the steel sheet in an Al bath to form an Al plating layer on the surface.

(8) The method of production of steel sheet for a hot stamped member as set forth in any one of (4) to (6) which further includes, after the recrystallization-annealing step, a step of dipping the steel sheet in a galvanization bath to form a galvanized layer on the surface.

(9) The method of production of steel sheet for a hot stamped member as set forth in any one of (4) to (6) which further includes, after the recrystallization annealing step, a step of dipping the steel sheet in a Zn bath to form a galvanized layer on the surface, then further heating to 600°C or less to form a Zn-Fe alloy layer on the surface.

Advantageous Effects of Invention

[0024] The steel sheet for a hot stamped member of the present invention can be produced by a known steelmaking facility. Further, a shaped part which is obtained using the steel sheet for a hot stamped member of the present invention for shaping by widespread hot stamping facilities (hot stamped members) has a fatigue characteristic equal to "ordinary high strength steel sheet" of the same strength, so has the effect of expanding the scope of application of hot stamped members (parts).

Brief Description of Invention

[0025]

FIG. 1 is perspective view which shows a sheet press die for hot stamping which is used for the examples of the present invention. FIG. 2 is a view which shows fatigue test pieces.

FIG. 3 is a perspective view which shows locations of measurement of hardness in a test piece for hardness measurement use of the same dimensions as the crack growth region of the fatigue test piece which is shown in FIG. 2. FIG. 4 is a graph which shows the correlation between the fatigue limit ratio and standard deviation of hardness before hot stamping of steel sheet for a hot stamped member of Example 1.

FIG. 5 is a perspective view which schematically shows steel sheet (member) which is formed into a hat shape by the hot stamping method.

FIG. 6 is a graph which shows the correlation between the fatigue limit ratio and standard deviation of hardness before hot stamping of steel sheet for a hot stamped member of Example 2.

Description of Embodiments

[0026] The inventors engaged in research using steel sheet which contains, by mass%, C: 0.23%, Si: 0.5%, and Mn: 1.6% to prepare a hot stamped member and evaluated its characteristics. They discovered that the fatigue characteristic is one of the same but that there are hot stamped members which are the same in composition of the steel sheet and almost the same in tensile strength, but differ in fatigue characteristic. Therefore, they investigated the differences of these in detail, whereupon they learned that there are differences in the deviation in hardness near the surface layers of hot stamped members. Accordingly, they further changed the composition and recrystallization conditions of cold rolled steel sheet over a broad range to investigate the fatigue characteristic of hot stamped members and discovered that there is a strong correlation between the fatigue characteristic of hot stamped members and the deviation in surface hardness of the same and that to obtain a hot stamped member which is excellent in fatigue characteristic, it is effective to make the various in surface hardness of steel sheet before hot stamping within a predetermined range and that further to obtain such steel sheet, it is possible to control the conditions when recrystallization-annealing cold rolled steel sheet to a predetermined range.

[0027] Details will be explained in the examples, but the inventors used these test findings as the basis to experimentally clarify the suitable range of deviation in hardness and the annealing conditions and thereby completed the present invention.

Composition of Steel Sheet

[0028] First, the composition of steel sheet will be explained. Here, the "%" in the composition mean mass%.

C: 0.15 to 0.35%

[0029] C is the most important element in increasing the strength of steel sheet by hot stamping. To obtain a 1200 MPa or so strength after hot stamping, 0.15% or more has to be included. On the other hand, if over 0.35% is included, deterioration of toughness is a concern, so 0.35% is made the upper limit.

Si: 0.01 to 1.0%

[0030] Si is a solution strengthening element. Up to 1.0% can be effectively utilized. However, if more than that is

included, trouble is liable to occur at the time of chemical treatment or coating after shaping, so 1.0% is made the upper limit. The lower limit is not particularly limited. The effect of the present invention can be obtained. However, reduction more than necessary just raises the steelmaking load, so the content is made the level of inclusion due to deoxidation, that is, 0.01% or more.

Mn: 0.3 to 2.3%

[0031] Mn is an element which functions as a solution strengthening element in the same way as Si and also is effective for raising the hardenability of steel sheet. This effect is recognized at 0.3% or more. However, even if over 2.3% is included, the effect becomes saturated, so 2.0% is made the upper limit.

P: 0.03% or less, S: 0.02% or less

[0032] The two elements are both unavoidable impurities. They affect the hot workability, so have to be limited to the above ranges.

Al: 0.01 to 0.5%

[0033] Al is suitable as a deoxidizing element, so 0.01% or more should be included. However, if included in a large amount, coarse oxides are formed and the mechanical properties of the steel sheet are impaired, so the upper limit is made 0.5%.

N: 0.1% or less

[0034] N is an unavoidable impurity. It easily bonds with Ti or B, so has to be controlled so as not to reduce the targeted effect of these elements. 0.1% or less is allowable. The content is preferably 0.01% or less. On the other hand, reduction more than necessary places a massive load on the production process, so 0.0010% should be made the target for the lower limit.

Cr: 0.01 to 2.0%

[0035] Cr has the effect of raising the hardenability, so can be suitably used. This effect becomes clear at 0.01% or more. On the other hand, even if over 2.0% is added, this effect becomes saturated, so 2.0% is made the upper limit.

Ti: 0.001 to 0.5%

[0036] Ti is an element which acts to stably draw out the effect of B, explained later, through the formation of its nitride, so can be effectively used. For this reason, 0.001% or more has to be added, but if excessively added, the nitrides become excessive and deterioration in toughness or shear surface properties is invited, so 0.5% is made the upper limit.

Nb: 0.001 to 0.5%

[0037] Nb is an element which forms carbonitrides and raises the strength, so can be effectively used. This effect is recognized at 0.001% or more, but if over 0.5% is included, the controllability of the hot rolling is liable to be impaired, so 0.5% is made the upper limit.

B: 0.0005 to 0.01%

[0038] B is an element which raises the hardenability. The effect becomes clear at 0.0005% or more. On the other hand, excessive addition leads to deterioration of hot workability and a drop in the ductility, so 0.01% is made the upper limit.

Mo: 0.01 to 1.0%, W: 0.01 to 0.5%, V: 0.01 to 0.5%

[0039] These elements all have the effect of raising the hardenability, so can be suitably used. The effect becomes clear in each case at 0.01% or more. On the other hand, it is an expensive element, so the concentration where the effect becomes saturated is preferably made the upper limit. For Mo, this is 1.0%, while for W and V, it is 0.5%.

Cu: 0.01 to 1.0%

[0040] Cu has the effect of raising the strength of the steel sheet by addition of Cu in 0.01% or more. However, excessive addition detracts from the surface quality of the hot rolled steel sheet, so 1.0% is made the upper limit.

Ni: 0.01 to 5.0%

[0041] Ni is an element which has the effect of raising the hardenability, so can be effectively used. The effect becomes clear at 0.01% or more. On the other hand, it is an expensive element, so 5.0% where the effect becomes saturated is made the upper limit. Further, it also acts to suppress the drop in the surface quality of the hot rolled steel sheet due to Cu, so inclusion simultaneously with Cu is desirable.

[0042] Note that in the present invention, the composition other than the above consist of Fe, but unavoidable impurities which enter from the scrap and other melting materials or the refractories etc. are allowed.

[0043] Deviations in Steel Sheet Surface Hardness The deviations in steel sheet surface hardness will be explained.

[0044] First, the method of determining (measuring) the hardness of the steel sheet surface will be explained.

[0045] The hardness of the steel sheet surface ideally should be measured by a hardness meter (for example Vicker's hardness meter) with the steel sheet surface facing upward and with the sheet thickness direction matched with the vertical direction, but to clearly determine indentations (measure dimensions of indentations precisely), the surface (measurement surface) has to be polished or other certain work is necessary. In such work (for example, mechanical polishing), at least several dozen μm or so are removed from the original surface. Further, even if removing part of the surface using an acid etc. to chemically polish it, there is no difference. Rather, the smoothness is often degraded. Therefore, using such a technique to determine (measure) the hardness of the steel sheet surface is not practical.

[0046] Therefore, the inventors decided to determine the hardness at a cross-section parallel to the sheet thickness direction of the steel sheet. By doing so, the steel sheet surface can be measured without working it (without removing the steel sheet surface). However, in this case as well, the position able to be measured by a hardness meter in this way is inside from the surface a slight amount in the sheet thickness direction. For this reason, as a next best solution, the inventors attempted to obtain information on a portion close to the surface by making an indentation by as low a load as possible.

[0047] Specifically, refer to FIG. 3. First, the measurement surface (steel sheet cross-section) was polished to a mirror finish. A Vicker's hardness meter was used with a test load (load pushing in indenter) of 10 gf, a pushing time of 15 seconds, and a measurement position in the sheet thickness direction of 20 μm from the steel sheet surface. The "hardness of the steel sheet" as used in the Description indicates the hardness determined based on the above technique.

[0048] Further, the hardness of the steel sheet surface in steel sheet which has as a surface layer of the steel sheet either an Al plating layer, galvanized layer, and Zn-Fe alloy layer was measured at a position 20 μm from the boundary (interface) between the plating layer and the steel sheet.

[0049] For example, the Al plating layer of the steel sheet which is used in the examples is deemed to be comprised of an outside layer which has Al as its main composition and an inside (steel sheet side) layer which is believed to be a reaction layer of Al and Fe, so the hardness was measured at a position 20 μm from the boundary of the inside layer and the steel sheet in the sheet thickness direction and this was used as the surface hardness of the steel sheet.

[0050] Next, the galvanized layer of the steel sheet which is used in the examples is deemed to be comprised of two layers of an outside layer which has Zn as its main composition and an inside layer which is a reaction layer of Al which was added in a fine amount in the Zn bath and Fe, so the hardness was measured at a position 20 μm from the boundary of the inside layer and the steel sheet in the sheet thickness direction and this was used as the surface hardness of the steel sheet.

[0051] Further, the Zn-Fe alloy layer of the steel sheet which is used in the examples is deemed to be comprised of a plurality of alloy layers which are comprised of Zn and Fe, so the hardness was measured at a position 20 μm from the boundary of the inside-most layer and the steel sheet in the sheet thickness direction and this was used as the surface hardness of the steel sheet.

[0052] For the purpose of finding the deviation in hardness, the above measurement was performed in the region corresponding to the fatigue crack growth region (21) of the fatigue test piece which is shown in FIG. 2. FIG. 3 is a perspective view which shows the location of measurement of the hardness. The indenter of the Vicker's hardness meter was pushed in at a position of 20 μm from the surface or the steel sheet or the interface of the steel sheet and the plating layer in the sheet thickness direction. This operation, as shown in FIG. 3, was performed at indentation intervals of 0.1 mm in a direction parallel to the surface of the steel sheet at 300 points per measurement sample (over 30 mm by measurement length) (first measurement surface). Further, the same operation was performed at another location 5 mm from the first measurement surface taken in advance (second measurement surface).

[0053] The hardnesses were found for the total 600 points in this way. The standard deviation using this as the population was calculated and used as an indicator of the deviation.

[0054] Note that the above measurement length of 30 mm and the two locations 5 mm apart were determined so as to match with the crack growth region of the fatigue test piece which is explained later.

[0055] In the experiment which is explained in the examples, samples with a fatigue limit ratio after hot stamping of 0.4 or more and ones with a ratio below that were compared for deviation in hardness of the steel sheet surface, whereupon in the former, the standard deviation was 40 or less. Therefore, the inventors proceeded with more detailed investigations, whereupon it became clear that the deviation in hardness after hot stamping has a standard deviation of 40 or less when the deviation in hardness of the steel sheet before hot stamping, determined by a similar technique, has a standard deviation of 20 or less.

[0056] In the present invention, the standard deviation of the Vicker's hardness at a position 20 μm from the steel sheet surface in the sheet thickness direction was defined as 20 or less based on such experimental findings.

Method of Production of Steel Sheet for Hot Stamped Member

[0057] Finally, the method of production of steel sheet for a hot stamped member of the present invention will be explained.

[0058] The steel sheet for a hot stamped member of the present invention is processed in the accordance with the usual methods by the steps of steelmaking, casting, hot rolling, pickling, and cold rolling to obtain cold rolled steel sheet. The composition is adjusted to the above-mentioned scope of the present invention in the steelmaking step, the steel is cast to a slab in the continuous casting step, then the slab is started to be hot rolled at for example a 1300°C or less heating temperature. The rolling is ended around 900°C. The coiling temperature can be selected as, for example 600°C etc. The hot rolling rate may be made 60 to 90%. The cold rolling is performed after the pickling step. The rolling rate can be selected from 30 to 90% in range.

[0059] The annealing step for recrystallizing the cold rolled steel sheet which was produced in this way is extremely important. The annealing step is performed using a continuous annealing facility and is comprised of two stages of a first step of heating by an average heating rate of 8 to 25°C/sec from room temperature to the temperature M (°C) and a second stage of then heating by an average heating rate of 1 to 7°C/sec down to a temperature S (°C). Here, the temperature M has to be 600 to 700(°C), and the temperature S has to be 720 to 820(°C). These conditions are determined based on the results of the experiment which is explained in the examples which are described below.

[0060] The reason why, when recrystallization-annealing under these conditions, the standard deviation of the Vicker's hardness which was measured at a position of 20 μm from the steel sheet surface in the sheet thickness direction is 20 or less, that is, steel sheet with a small deviation in hardness is obtained, is not necessarily clear, but the distribution of crystal grain size is preferably as uniform as possible and the dimensions and distribution of carbides are also preferably similarly as uniform as possible, so the following may be guessed from the viewpoint of the distribution of recrystallized particle size and the dimensions and distribution of carbides.

[0061] The recrystallization process of cold rolled steel sheet is complicated, so it is not suitable to separate and independently discuss the meanings of the heating rate for the phenomenon called recrystallization and the highest heating temperature at that heating rate. Therefore, first, regarding the first stage, for example, consider the case where the heating rate is small and where it is large with respect to a certain single temperature M (°C). It is believed that in the former case, that is, when the heating rate is small, the density of recrystallization nuclei is (relatively) low and the individual recrystallized grains freely grow, but in the high temperature region near M (°C), fine recrystallized grains are produced from the remaining non-recrystallization region and, at the stage where the temperature of the steel sheet reaches M(°C), (relatively) large crystal grains and small crystal grains are mixed.

[0062] On the other hand, it is believed that in the case of the latter, that is, when the heating rate is large, the density of recrystallized grain nuclei is high, a large number of recrystallized grains grow at a fast rate, and the grain boundaries become closer and further, in the high temperature region near M (°C), the recrystallized grains compete in growth and as a result crystal grains which have specific crystal orientations grow while eating away at crystal grains which have other crystal orientations, so at the stage when reaching M (°C), it is believed there are large crystal grains and small crystal grains mixed together. Therefore, a combination of the suitable heating rate and M (°C) whereby the recrystallized grains become close in grain boundaries at the stage where the temperature reaches M (°C) becomes necessary for achieving a more uniform distribution of recrystallized particle sizes. The 8 to 25°C/sec of the average heating rate of the first stage and the 600 to 700°C of the temperature M (°C) are believed to correspond to these suitable conditions.

[0063] Next, to control competition of growth of recrystallized grains after the temperature of the steel sheet reaches M (°C), the heating rate of the second stage has to be made smaller than the first stage. Further, in the temperature region from the temperature M (°C) to the temperature S (°C), reformation of carbides due to the diffusion of carbon becomes active, so the combination of the setting of the highest temperature S (°C) of the annealing step and the heating rate up to that temperature has important meaning.

[0064] When the heating rate is small for one S (°C), the carbides which were present at the temperature M (°C) uniformly grow, so it may be that a steel sheet results in which carbides of various dimensions which were present in

the stage when reaching the temperature M (°C) are present in various ways. On the other hand, when the heating rate is large, small carbides disappear and large carbides grow and therefore the dimensions of the carbides become closer to uniform ones relatively speaking, but the density becomes small. Therefore, unevenness of hardness of the steel sheet is caused due to the carbides. As opposed to these, when the combination of the heating rate and the temperature S (°C) of the second stage is suitable, the small carbides grow preferentially and it may be that a steel sheet results in which relatively uniform dimension carbides are dispersed at a suitable density, so the unevenness of hardness of the steel sheet due to carbides becomes uneven. The 1 to 7°C/sec of the heating rate of the second stage and the 720 to 820°C of the temperature S (°C) correspond to such suitable conditions.

[0065] After reaching the temperature S, the temperature S may be held for a short time or the next cooling step may be immediately shifted to. When holding the temperature S, from the viewpoint of coarsening of the crystal grains, the holding time is preferably 180 seconds or less, more preferably 120 seconds or less.

[0066] The cooling rate from the temperature S in the cooling step is not particularly limited, but 30°C/sec or more rapid cooling is preferably avoided. Therefore, the cooling rate from the temperature S is less than 30°C/sec, preferably 20°C or less, more preferably 10°C or less. Steel sheet for hot stamping use is often sheared to a predetermined shape and then used for hot stamping. This is because it is feared that rapid cooling raises the shear load and lowers the production efficiency.

[0067] After annealing, the sheet may be cooled down to room temperature. During cooling, it may be dipped in a hot dip Al bath to form an Al plating layer.

[0068] The hot dip Al bath may contain 0.1 to 20% of Si.

[0069] The Si which is contained in the Al plating layer affects the reaction of Al and Fe which occurs during heating before hot stamping. Excessive reaction is liable to detract from the press formability of the plating layer itself. On the other hand, excessive control of the reaction is liable to invite adherence of Al on the press forming die. To avoid such a problem, the content of Si in the Al plating layer is preferably 1 to 15%, more preferably 3 to 12%.

[0070] Further, during the cooling after annealing, the sheet was dipped in a hot dip galvanization bath to form a galvanized layer.

[0071] Furthermore, the sheet was dipped in a hot dip galvanization bath to form a galvanized layer, then was heated to 600°C or less to form a Zn-Fe alloy layer.

[0072] The hot dip galvanization bath could contain 0.01 to 3% of Al.

[0073] The existence of Al has a strong affect on the reaction of Zn and Fe. When forming a galvanized layer, the reaction layer of the Fe and Al becomes an obstacle and suppresses mutual dispersion of Zn and Fe. On the other hand, a Zn-Fe alloy layer is comprised of a Zn-rich alloy layer (ζ -phase, δ_1 -phase) and Fe-rich alloy layer (Γ_1 -phase, Γ -phase), but the former is rich in adhesion with the base iron, but the workability is degraded, while the latter is excellent in workability, but is insufficient in adhesion. Therefore, it is necessary to suitably control the ratio of composition of these four phases to satisfy the targeted properties (giving preference to adhesion, giving preference to workability, or balancing the two etc.) This can be performed by including in the hot dip galvanization bath 0.01 to 3% of Al so as to enable control of the diffusion of Fe. What sort of concentration to use may be selected by the manufacturer in accordance with the ability or objective of the production facility.

[0074] The thicknesses of the Al plating layer, galvanized layer, and Zn-Fe alloy layer do not influence the fatigue characteristic of the steel sheet after hot stamping or the fatigue characteristic of the parts, but if excessively thick, the press formability is liable to be affected. As shown in the examples, when the thickness of the Al plating layer is over 50 μm , the phenomenon of galling is recognized. When the thickness of the Zn plating layer exceeds 30 μm , adhesion of the Zn to the die frequently occurs. When the thickness of the Zn-Fe alloy layer is over 45 μm , scattered cracking of the alloy layer is seen, and the productivity is otherwise impaired. Therefore, the thicknesses of the layers are preferably made Al plating layer: 50 μm or less, galvanized layer: 30 μm or less, and Zn-Fe alloy layer: 45 μm or less.

[0075] When these plating layers are thin, there is no problem at all in shapeability, but from the viewpoint of the corrosion resistance, which is aimed at imparting these plating layers, the lower limits of the plating layers are preferably made as follows: That is, the limits are the Al plating layer: preferably 5 μm or more, more preferably 10 μm or more, the galvanized layer: preferably 5 μm or more, more preferably 10 μm or more, and the Zn-Fe alloy layer: preferably 5 μm or more, more preferably 10 μm or more.

Examples

[0076] Below, examples will be used as the basis to explain the present invention in detail.

Example 1

[0077] Steels "a" to "f" which have the composition which is shown in Table 1 were produced and cast. The slabs were heated to 1250°C and supplied to a hot rolling step where they were hot rolled at a final temperature of 900°C and a

coiling temperature of 600°C to obtain thickness 3.2 mm steel sheets. These hot rolled steel sheets were pickled, then cold rolled to obtain thickness 1.6 mm cold rolled steel sheets.

[0078] The cold rolled steel sheets were recrystallized and annealed under the conditions of i to xviii described in Table 2 to obtain the steel sheets for hot stamped members 1 to 32 which are shown in Table 3. From part, two test pieces for measurement of the hardness before hot stamping were obtained. The positions for sampling the test pieces were made positions 5 mm separated in the width direction of the obtained steel sheet for hot stamped member.

[0079] The average heating rate 1 (first stage) and average heating rate 2 (second stage) in Table 2 respectively show the average heating rates from room temperature to temperature M (°C) and the average heating rate from temperature M (°C) to the temperature S (°C).

[0080] These steel sheets for hot stamped members were held at 900°C for 10 minutes, then were sandwiched by the test-use sheet press die which was shown in FIG. 1 and hot stamped. Each type of steel sheet for a hot stamped member was used hot stamping 10 pieces. From one among these, two tensile test pieces based on the provisions of JIS No. 5 and two test pieces for measurement of hardness (same procedure as with hot stamping) were obtained. From the remaining nine, two fatigue test pieces which are shown in FIG. 2 each, for a total of 18, were obtained. The method of working for obtain test pieces was electrodischarge machining.

[0081] A tensile test was performed to find the tensile strength σ_B (average value of two tensile test pieces). On the other hand, 18 test pieces were used to run a plane bending fatigue test and determine the 1×10^7 cycle fatigue strength σ_W . The test conditions were a stress ratio of -1 and a repetition rate of 5Hz.

[0082] The test pieces for measurement of hardness were polished to a mirror finish at cross-sections parallel to the rolling directions of cold rolled steel sheets both before and after hot stamping.

[0083] The hardness at 20 μ m inside from the surfaces of these test pieces in the sheet thickness direction was measured using a Vicker's hardness meter (HM-2000 made by Mitsutoyo). The pushing load was made 10 gf, the pushing time was made 15 seconds, and the measurement interval in the direction parallel to the surface made 0.1 mm for measurement of 300 points.

[0084] Two test pieces were measured in the same way. The standard deviation of hardness was calculated from the data of the Vicker's hardness of a total of 600 points.

[0085] Table 3 shows the steel number, processing conditions, standard deviation of hardness before hot stamping, tensile strength σ_B (average of two), strength σ_W , fatigue limit ratio σ_W/σ_B , and standard of hardness after hot stamping. The correlation between the fatigue limit ratio σ_W/σ_B and the standard deviation of hardness before hot stamping is shown in FIG. 4.

[0086] It was learned that the tensile strength σ_B of steel sheet after hot stamping is almost entirely unaffected by the recrystallization-annealing conditions in steel sheet of the same composition (code "b"). On the other hand, the fatigue characteristics (σ_W/σ_B) were strongly affected by the recrystallization-annealing conditions.

[0087] In steel sheets using the annealing conditions i, iii, iv, vii, viii, xv, and xviii of the present invention, relatively high fatigue characteristics, that is, a 0.4 or more fatigue limit ratio (σ_W/σ_B), could be obtained in the range of about 1200 to 1500 MPa in tensile strength. As opposed to this, in steel sheets which were annealed under conditions outside the scope of the present invention, the obtained fatigue limit ratio was a low level of about 0.3.

[0088] This difference is due to the fact that the fatigue limit ratio is correlated with the standard deviation of hardness after hot stamping. Simultaneously, it clearly depends on the standard deviation of the hardness before hot stamping. As shown in Nos. 1 to 6, 8, 9, 12, 13, 16, 17, 20, 21, and 23 to 28, it became clear that when the standard deviation of the hardness is 2 or less, a hot stamped member which has an excellent fatigue characteristic (high fatigue limit ratio) is obtained.

[0089] Further, as the conditions of recrystallization-annealing for obtaining steel sheet with a standard deviation of hardness before hot stamping of 20 or less, there are a first stage of heating by an average heating rate of 15 to 25°C/sec from room temperature to a temperature M (°C) and a second stage of then heating by an average heating rate of 2 to 5°C/sec to the temperature S (°C). It became clear that M is 620 to 680 (°C) and S is 780 to 820 (°C).

Table 1

Steel no.	C	Si	Mn	P	S	Al	N	Others
a	0.25	0.7	1.9	0.02	0.002	0.03	0.004	Ti : 0.03, B: 0.003
b	0.23	0.5	1.6	0.02	0.002	0.03	0.003	
c	0.21	0.3	1.4	0.02	0.002	0.03	0.002	B: 0.004
d	0.20	0.2	1.2	0.02	0.002	0.03	0.004	Cr: 0.2, Ti: 0.02, B: 0.002
e	0.18	0.2	1.3	0.02	0.002	0.03	0.003	Cr: 1.4, Ti: 0.02, B: 0.002

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(continued)

Steel no.	C	Si	Mn	P	S	Al	N	Others
f	0.15	0.3	1.1	0.02	0.002	0.03	0.003	Cr: 0.1, B: 0 004
Units are mass%.								

Table 2

Condition no.	Average heating rate 1 (°C/sec)	Temp. M (°C)	Average heating rate 2 (°C/sec)	Temp. S(°C)	Cooling conditions	
i	20	650		800	No holding Cooling by average cooling rate 6°C/sec to 670°C, holding for 10 seconds, then air cooling to room temperature.	Inv. ex.
ii	25	<u>590</u>	3	800	Ditto	Comp. ex.
iii	25	600	3	800	Ditto	Inv. ex.
iv	8	700	3	800	Ditto	Inv. ex.
v	8	<u>710</u>	3	800	Ditto	Comp. ex.
vi	15	650	7	<u>830</u>	Ditto	Comp. ex.
vii	15	650	7	820	Ditto	Inv. ex.
viii	15	650	2	720	Ditto	Inv. ex.
ix	15	650	2	<u>710</u>	Ditto	Comp. ex.
x	<u>7</u>	600	4	800	Ditto	Comp. ex.
xi	8	600	4	800	Ditto	Inv. ex.
xii	25	700	3	800	Ditto	Inv. ex.
xiii	<u>26</u>	700	3	800	Ditto	Comp. ex.
xiv	20	650	<u>0.5</u>	720	Ditto	Comp. ex.
xv	20	650	<u>1</u>	720	Ditto	Inv. ex.
xvi	20	650	<u>7</u>	820	Ditto	Inv. ex.
xvii	20	650	<u>8</u>	820	Ditto	Comp. ex.
xviii	20	650	3	800	Holding for 10 sec., then air cooling to room temperature	Inv. ex.
Underlined figures indicate outside scope of present invention.						

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Table 3

No.	Steel no.	Processing conditions	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B (fatigue limit ratio)	Standard deviation of hardness after hot stamping	
1	a	i	10	1510	619	0.41	27	Inv. ex.
2	b	i	9	1508	603	0.40	22	Inv. ex.
3	c	i	6	1501	630	0.42	20	Inv. ex.
4	d	i	8	1498	614	0.41	21	Inv. ex.
5	e	i	11	1503	646	0.43	27	Inv. ex.
6	f	i	7	1422	597	0.42	24	Inv. ex.
7	b	ii	<u>30</u>	1512	484	0.32	46	Comp. ex.
8	b	iii	12	1506	602	0.40	20	Inv. ex.
9	b	iv	16	1489	610	0.41	23	Inv. ex.
10	b	v	<u>29</u>	1502	451	0.30	42	Comp. ex.
11	b	vi	<u>24</u>	1499	465	0.31	44	Comp. ex.
12	b	vii	1	1505	647	0.43	19	Inv. ex.
13	b	viii	11	1516	637	0.42	22	Inv. ex.
14	b	ix	<u>24</u>	1511	453	0.30	43	Comp. ex.
15	b	x	<u>32</u>	1522	502	0.33	51	Comp. ex.
16	b	xi	16	1518	638	0.42	24	Inv. ex.
17	b	xii	19	1512	650	0.43	26	Inv. ex.
18	b	xiii	33	1507	452	0.30	49	Comp. ex.
19	b	xiv	29	1500	480	0.32	46	Comp. ex.
20	b	xv	12	1496	598	0.40	22	Inv. ex.
21	b	xvi	11	1506	617	0.41	25	Inv. ex.
22	b	xvii	27	1503	496	0.33	45	Comp. ex.
23	a	xviii	10	1510	631	0.42	19	Inv. ex.
24	b	xviii	6	1512	605	0.40	12	Inv. ex.
25	c	xviii	8	1503	601	0.40	14	Inv. ex.
26	d	xviii	13	1509	649	0.43	24	Inv. ex.
27	e	xviii	18	1499	600	0.40	27	Inv. ex.
28	f	xviii	11	1418	610	0.43	22	Inv. ex.
Underlined figures indicate outside scope of present invention.								

Example 2

[0090] Steels 2a to 2h which have the composition which is shown in Table 4 were produced and cast. The slabs were hot rolled under the same conditions as Example 1 to obtain thickness 3.0 mm steel sheets. These hot rolled steel sheets were pickled, then cold rolled to 1.2 mm.

[0091] These steel sheets were recrystallized and annealed under conditions of i, ix, and xviii of Table 2 to obtain steel sheets for hot stamped members.

[0092] From these steel sheets, test pieces for measurement of hardness were obtained by the same procedure as in Example 1.

[0093] These steel sheets for a hot stamped member were held at 900°C for 5 minutes, then were formed to hat shapes which are shown in FIG. 5 by the hot stamping method. As shown in this figure, fatigue test pieces which are shown in FIG. 2 and JIS No. 5 tensile test pieces were obtained from the top parts of the hats.

[0094] These test pieces were used by the same procedure as in Example 1 to find the standard deviation of hardness before hot stamping and the tensile strength σ_B (average of two) and 1×10^7 cycle fatigue strength σ_W of the steel sheet after hot stamping (member).

[0095] Table 5 shows these results. The correlation between the fatigue limit ratio σ_W/σ_B and the standard deviation of the hardness before hot stamping is shown in FIG. 6.

[0096] In steel sheets for a hot stamped member which were recrystallized and annealed using conditions i and xviii in the scope of the present invention, even if steel sheets which contain Mo, W, V, Cu, and Ni, the deviation in hardness of the surface layer before hot stamping had a standard deviation of 20 or less. Further, if using these, it became clear that a hot stamped member with a fatigue limit ratio of 0.4 or more, that is, excellent in fatigue characteristic, was obtained.

[0097] On the other hand, in steel sheets which were recrystallized and annealed using the condition ix which is outside the scope of the present invention, the deviation in hardness of the surface layer before hot stamping has a standard deviation of over 20. The fatigue limit ratio of the hot stamped members obtained by using these was 0.26 to 0.31. It became clear the fatigue characteristic was inferior.

Table 4

Steel no.	Composition (mass%)							
	C	Si	Mn	P	S	Al	N	Others
2a	0.35	0.3	1.0	0.02	0.004	0.03	0.004	Cr: 0.2 Ti: 0.01, B: 0.002, Cu 0.1, Ni : 0.1
2b	0.31	1.5	1.2	0.02	0.004	0.03	0.004	Cr: 0.5, Ti: 0.02, B: 0.004, Nb 0.02, Mo: 0.2
2c	0.28	1.0	1.7	0.02	0.004	0.03	0.004	W: 0.2 Ni: 2.0
2d	0.25	0.8	1.9	0.02	0.004	0.03	0.004	Ti: 0.03, B: 0.003, Mo: 0.2 Ni: 1.0
2e	0.23	0.8	1.6	0.02	0.004	0.03	0.003	Mo 0.1 W: 0.5, V: 0.5
2f	0.21	0.4	1.4	0.02	0.004	0.03	0.002	B: 0.004, Mo: 0.1, V: 0.5
2g	0.20	0.3	1.2	0.02	0.004	0.03	0.004	Cr 0.2, Ti: 0.02, Mo: 0.2, W: 0.4
2h	0.18	0.3	1.3	0.02	0.004	0.03	0.003	Cr: 1.4 Ti: 0.02, R: 0.002, Mo: 0.1, V: 0.2

Table 5

No	Steel no.	Processing conditions	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B , (fatigue limit ratio)	
29	2a	i	18	1794	718	0.40	Inv. ex.
30	2a	ix	40	1790	465	0.26	Comp. ex.
31	2a	xviii	19	1802	721	0.40	Inv. ex.

(continued)

No	Steel no.	Processing conditions	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B , (fatigue limit ratio)	
32	2b	i	16	1706	682	0.40	Inv. ex.
33	2b	ix	<u>37</u>	1696	441	0.26	Comp. ex.
34	2b	xviii	18	1711	702	0.41	Inv. ex.
35	2C	i	15	1598	639	0.40	Inv. ex.
36	2C	ix	<u>30</u>	1592	430	0.27	Comp. ex.
37	2C	xviii	14	1590	636	0.40	Inv. ex.
38	2d	i	15	1492	612	0.41	Inv. ex.
39	2d	iv	<u>26</u>	1500	435	0.29	Comp. ex.
40	2d	xviii	5	1498	614	0.41	Inv. ex.
41	2e	i	9	1492	597	0.4	Inv. ex.
42	2e	ix	<u>31</u>	1502	421	0.28	Comp. ex.
43	2e	xviii	10	1516	622	0.41	Inv. ex.
44	2f	i	12	1508	603	0.4	Inv. ex.
45	2f	ix	36	1512	462	0.31	Comp. ex.
46	2f	xviii	19	1522	609	0.4	Inv. ex.
47	2g	i	14	1496	613	0.41	Inv. ex.
48	2g	ix	<u>33</u>	1504	406	0.27	Comp. ex.
49	2g	xviii	13	1526	641	0.42	Inv. ex.
50	2h	i	14	1506	602	0.4	Inv. ex.
51	2h	ix	32	1512	454	0.3	Comp. ex.
52	2h	xviii	15	1528	64	0.42	Inv. ex.
Underlined figures indicate outside scope of present invention.							

Example 3

[0098] Steels 3a to 3d which have the composition which is shown in Table 6 were produced and cast. The slabs were hot rolled under the same conditions as Example 1 to obtain thickness 2.5 mm steel sheets. These hot rolled steel sheets were pickled, then cold rolled to 1.2 mm.

[0099] These steel sheets were heated by an average heating rate of 19°C/sec up to 655°C, then were heated by an average heating rate of 2.5°C to 800°C, then were immediately cooled by an average cooling rate of 6.5°C/sec. Further, they were dipped in a 670°C hot dip Al bath (containing 10% of Si and unavoidable impurities), taken out after 5 seconds, adjusted in amount of deposition by a gas wiper, then air cooled down to room temperature.

[0100] From the obtained steel sheets, the same procedure as in Example 1 was used to obtain test pieces for measurement of hardness. To measure the hardness, the hardness at a position 20 μ m from the boundary of the inside layer of the Al plating layer (reaction layer of Al and Fe) and the steel sheet was measured by the same procedure as in Example 1. At the time of this measurement, the thickness of the Al plating layer (total of two layers) was also measured. The range of measurement of thickness was made the same length 30 mm as the range of measurement of hardness. Seven points were measured at measurement intervals of 5 mm at each of the first measurement surface and second measurement surface for a total of 14 measurement positions. The average value was found.

[0101] These steel sheets were hot stamped into hat shapes by the same procedure as in Example 2. The heating conditions were holding at 900°C for 1 minute.

[0102] From the top parts of the hats, fatigue test pieces which are shown in FIG. 2 and JIS No. 5 tensile test pieces

were obtained.

[0103] These test pieces were used to find the tensile strength σ_B (average of two) and 1×10^7 cycle fatigue strength σ_W . Table 7 shows the results.

[0104] In all examples, excellent steel sheet for a hot stamped member with a fatigue limit ratio of 0.4 or more was obtained, but in Nos. 57, 62, 67, and 72 where the thickness of the Al plating layer exceeded 50 μm , a galling phenomenon occurred at a high frequency at the long wall parts of the hat shape. In examples of 50 μm or less, no galling phenomenon occurred at all. Therefore, it was judged that the upper limit of thickness when Al plating the steel sheet surface is 50 μm or less.

Table 6

Steel no.	C	Si	Mn	P	S	Al	N	Others
3a	0.33	0.09	1.8	0.01	0.004	0.04	0.003	Cr: 0.2, Mo: 0.2, Cu: 0.1, Ni: 0.05
3b	0.25	0.18	1.4	0.01	0.004	0.04	0.003	Cr: 0.002 Ti: 0.02, B: 0.003, Mo: 0.2, W: 0.1 V: 0.1
3C	0.22	0.12	1.3	0.02	0.008	0.03	0.004	Cr: 0.13, Ti: 0.03 Nb: 0.02, B: 0.002
3d	0.15	0.33	1.0	0.02	0.008	0.03	0.004	B: 0.0005
Units are mass%.								

Table 7

No	Steel no.	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B (fatigue limit ratio)	Thickness of Al plating layer (μm)	
53	3a	17	1784	714	0.40	16.0	Inv. ex.
54	3a	18	1789	716	0.40	22.2	Inv. ex.
55	3a	16	1801	720	0.40	33.9	Inv. ex.
56	3a	14	1792	717	0.40	48.6	Inv. ex.
57	3a	14	1790	716	0.40	<u>51.0</u>	Comp. ex.
58	3b	12	1516	652	0.43	1.1	Inv. ex.
59	3b	15	1520	638	0.42	19.6	Inv. ex.
60	3b	19	1524	671	0.44	34.2	Inv. ex.
61	3b	18	1522	685	0.45	49.6	Inv. ex.
62	3b	20	1534	614	0.40	<u>54.7</u>	Comp. ex.
63	3C	11	1502	631	0.42	14.5	Inv. ex.
64	3C	14	1509	649	0.43	20.1	Inv. ex.
65	3C	9	1513	635	0.42	34.6	Inv. ex.
66	3C	13	1519	668	0.44	49.2	Inv. ex.
67	3C	18	1524	610	0.40	<u>55.3</u>	Comp. ex.
68	3d	10	1318	554	0.42	17.2	Inv. ex.
69	3d	10	1326	557	0.42	20.4	Inv. ex.
70	3d	8	1320	554	0.42	10.2	Inv. ex.
71	3d	14	1314	539	0.41	42.0	Inv. ex.

(continued)

No	Steel no.	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B (fatigue limit ratio)	Thickness of Al plating layer (μm)	
72	3d	15	1310	537	0.41	<u>53.6</u>	Comp. ex.
Underlined figures indicate outside scope of present invention							

Example 4

[0105] Steels 3a to 3d which have the composition which is shown in Table 6 were produced and cast. The slabs were hot rolled under the same conditions as Example 1 to obtain thickness 2.5 mm steel sheets. These hot rolled steel sheets were pickled, then cold rolled to 1.2 mm.

[0106] These steel sheets were heated by an average heating rate of 19°C/sec up to 655°C, then were heated by an average heating rate of 2.5°C to 800°C, then were immediately cooled by an average cooling rate of 6.5°C/sec. Further, they were dipped in a 460°C hot dip galvanization bath (containing 0.15% of Al and unavoidable impurities), taken out after 3 seconds, adjusted in amount of deposition by a gas wiper, then air cooled down to room temperature.

[0107] From the obtained steel sheets, the same procedure as in Example 1 was used to obtain test pieces for measurement of hardness. To measure the hardness, the hardness at a position 20 μm from the boundary of the inside layer of the Zn plating layer (reaction layer of Al and Fe) and the steel sheet was measured by the same procedure as in Example 1. At the time of this measurement, the thickness of only the Zn plating layer may also be measured. The range of measurement of thickness was made the same length 30 mm as the range of measurement of hardness. Seven points were measured at measurement intervals of 5 mm at each of the first measurement surface and second measurement surface for a total of 14 measurement positions. The average value was found.

[0108] These steel sheets were hot stamped into hat shapes by the same procedure as in Example 2. They were heated to 880°C and held for 5 seconds, then air-cooled down to 700°C and pressed.

[0109] From the top parts of the hats, fatigue test pieces which are shown in FIG. 2 and JIS No. 5 tensile test pieces were obtained.

[0110] These test pieces were used to find the tensile strength σ_B (average of two) and 1×10 cycle fatigue strength σ_W . Table 8 shows the results.

[0111] In all examples, excellent steel sheet for a hot stamped member with a fatigue limit ratio of 0.4 or more was obtained, but in Nos 77, 82, 87, and 92 where the thickness of the galvanized layer exceeded 30 μm , adhesion of Zn was observed at a high frequency in the die. In examples of 30 μm or less, no adhesion of Zn occurred at all. Therefore, it was judged that the upper limit of thickness when galvanizing the steel sheet surface is 30 μm or less.

Table 8

No.	Steel no.	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B (fatigue limit ratio)	Thickness of galvanized layer (μm)	
73	3a	17	1785	714	0.40	6.1	Inv. ex.
74	3a	17	1788	715	0.40	12.5	Inv. ex.
75	3a	16	1802	721	0.40	23.8	Inv. ex.
76	3a	13	1794	718	0.40	28.6	Inv. ex.
77	3a	5	1793	717	0.40	<u>31.0</u>	Comp. ex.
78	3b	12	1516	652	0.43	11.1	Inv. ex.
79	3b	15	1522	639	0.42	19.6	Inv. ex.
80	3b	19	1534	675	0.44	24.8	Inv. ex.
81	3b	18	1532	689	0.45	29.0	Inv. ex.
82	3b	20	1543	618	0.40	<u>33.7</u>	Comp. ex.

(continued)

No.	Steel no.	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W/σ_B (fatigue limit ratio)	Thickness of galvanized layer (μm)	
83	3c	10	1518	638	0.42	10.3	Inv. ex.
84	3c	14	1 36	660	0.43	17.2	Inv. ex.
85	3c	9	1524	640	0.42	19.6	Inv. ex.
86	3c	14	1539	677	0.44	29.3	Inv. ex.
87	3c	13	1544	618	0.40	<u>32.3</u>	Comp. ex.
88	3d	10	1336	561	0.42	11.2	Inv. ex.
89	3d	12	1342	564	0.42	17.4	Inv. ex.
90	3d	8	1318	554	0.42	20.2	Inv. ex.
91	3d	13	1320	541	0.41	28.0	Inv. ex.
92	3d	15	1330	545	0.41	<u>33.4</u>	Comp. ex.
Underlined figures indicate outside scope of present invention.							

Example 5

[0112] Steels 3a to 3d which have the composition which is shown in Table 6 were produced and cast. The slabs were hot rolled under the same conditions as Example 1 to obtain thickness 2.5 mm steel sheets. These hot rolled steel sheets were pickled, then cold rolled to 1.2 mm.

[0113] These steel sheets were heated by an average heating rate of 19°C/sec up to 655°C, then were heated by an average heating rate of 2.5°C to 800°C, then were immediately cooled by an average cooling rate of 6.5°C/sec. Further, they were dipped in a 460°C hot dip galvanization bath (containing 0.13% of Al, 0.03% of Fe, and unavoidable impurities), taken out after 3 seconds, adjusted in amount of deposition by a gas wiper, then heated to 480°C to form a Zn-Fe alloy layer, then air cooled down to room temperature.

[0114] From the obtained steel sheets, the same procedure as in Example 1 was used to obtain test pieces for measurement of hardness. To measure the hardness, the hardness at a position 20 μm from the boundary of the innermost layer of the Zn-Fe alloy layer (reaction layer of Zn and Fe) and the steel sheet was measured by the same procedure as in Example 1. At the time of this measurement, the total thickness of the Zn-Fe alloy layer (which was comprised of four layers) was also measured. At the time of this measurement, the thickness of the Al plating layer (total of two layers) was also measured. The range of measurement of thickness was made the same length 30 mm as the range of measurement of hardness. Seven points were measured at measurement intervals of 5 mm at each of the first measurement surface and second measurement surface for a total of 14 measurement positions. The average value was found.

[0115] These steel sheets were hot stamped into hat shapes by the same procedure as in Example 2. They were heated to 880°C and held for 5 seconds, then air-cooled down to 700°C and pressed.

[0116] From the top parts of the hats, fatigue test pieces which are shown in FIG. 2 and JIS No. 5 tensile test pieces were obtained.

[0117] These test pieces were used to find the tensile strength σ_B (average of two) and 1×10^7 cycle fatigue strength σ_W . Table 9 shows the results.

[0118] In all examples, excellent steel sheet for a hot stamped member with a fatigue limit ratio of 0.4 or more was obtained, but in Nos 97, 102, 107, and 112 where the thickness of the Zn-Fe alloy layer exceeded 45 μm , fine cracks occurred in the alloy layer after pressing. In examples of 45 μm or less, no fine cracks formed at all. Therefore, it was judged that the upper limit of thickness when forming a Zn-Fe alloy layer on the steel sheet surface is 45 μm or less.

Table 9

No.	Stell no.	Standard deviation of hardness before hot stamping	σ_B (MPa)	σ_W (MPa)	σ_W / σ_B (fatigue limit ratio)	Thickness of Zn-Fe alloy layer (μm)	
93	3a	17	1773	727	0.41	15.0	Inv. ex.
94	3a	16	1777	711	0.40	22.2	Inv. ex.
95	3a	17	1802	739	0.41	31.5	Inv. ex.
96	3a	14	1786	714	0.40	39.9	Inv. ex.
97	3a	13	1772	109	0.40	<u>46.0</u>	Comp. ex.
98	3b	12	1505	632	0.42	15.7	Inv. ex.
99	3b	18	1519	638	0.42	21.6	Inv. ex.
100	3b	19	1513	651	0.43	39.2	Inv. ex.
101	3b	18	1502	661	0.44	44.6	Inv. ex.
102	3b	14	1518	622	0.41	49.7	Comp. ex.
103	3C	11	1506	633	0.42	14.5	Inv. ex.
104	3C	14	1503	646	0.43	20.8	Inv. ex.
105	3C	9	1500	645	0.43	34.6	Inv. ex.
106	3C	12	1506	633	0.42	42.2	Inv. ex.
107	3C	19	1510	619	0.41	<u>45.3</u>	Comp. ex.
108	3d	17	1307	523	0.40	15.2	Inv. ex.
109	3d	11	1313	551	0.42	18.4	Inv. ex.
110	3d	8	1320	554	0.42	30.6	Inv. ex.
111	3d	14	1314	539	0.41	42.9	Inv. ex.
112	3d	15	1310	537	0.41	<u>48.6</u>	Comp. ex.
Underlined figures indicate outside scope of present invention							

Preference Signs List

[0119]

- 11a top die
- 11b bottom die
- 12 steel sheet
- 21 fatigue crack growth region
- 51 test piece sampling position

Claims

1. Steel sheet for a hot stamped member which includes composition which contains, by mass%,

C: 0.15 to 0.35%,
 Si: 0.01 to 1.0%,
 Mn: 0.3 to 2.3%,
 Al: 0.01 to 0.5%, and
 a balance of Fe and unavoidable impurities, and

limit the impurities to
P: 0.03% or less,
S: 0.02% or less, and
N: 0.1% or less,

wherein a standard deviation of Vicker's hardness at a position of 20 μm from the steel sheet surface in the sheet thickness direction is 20 or less.

2. The steel sheet for a hot stamped member as set forth in claim 1 which further contains, by mass%, one or more of elements selected from

Cr: 0.01 to 2.0%,
Ti: 0.001 to 0.5%,
Nb: 0.001 to 0.5%
B: 0.0005 to 0.01%,
Mo: 0.01 to 1.0%
W: 0.01 to 0.5%,
V: 0.01 to 0.5%,
Cu: 0.01 to 1.0%, and
Ni: 0.01 to 5.0%.

3. The steel sheet for a hot stamped member as set forth in claim 1 which has on the surface of said steel sheet one of a 5 μm to 50 μm thick Al plating layer, a 5 μm to 30 μm thick galvanized layer, or a 5 μm to 45 μm thick Zn-Fe alloy layer.

4. A method of production of steel sheet for a hot stamped member comprising recrystallization-annealing cold rolled steel sheet which includes composition which contains, by mass%,

C: 0.15 to 0.35%,
Si: 0.01 to 1.0%,
Mn: 0.3 to 2.3%,
Al: 0.01 to 0.5%, and
a balance of Fe and unavoidable impurities, and
limit the impurities to
P: 0.03% or less,
S: 0.02% or less, and
N: 0.1% or less,

in which step, including
a first stage of heating by an average heating rate of 8 to 25°C/sec from room temperature to a temperature M (°C) and then a second stage of heating by an average heating rate of 1 to 7°C/sec to a temperature S (°C), wherein the temperature M (°C) is 600 to 700 (°C) and the temperature S (°C) is 720 to 820 (°C).

5. The method of production of steel sheet for a hot stamped member as set forth in claim 4 wherein said steel further contains, by mass%, one or more of

Cr: 0.01 to 2.0%,
Ti: 0.001 to 0.5%,
Nb: 0.001 to 0.5%
B: 0.0005 to 0.01%,
Mo: 0.01 to 1.0%
W: 0.01 to 0.5%,
V: 0.01 to 0.5%,
Cu: 0.01 to 1.0%, and
Ni: 0.01 to 5.0%.

6. The method of production of steel sheet for a hot stamped member as set forth in claim 5 wherein a hot rolling rate in said hot rolling step is 60 to 90%, while a cold rolling rate of said cold rolling step is 30 to 90%.

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7. The method of production of steel sheet for a hot stamped member as set forth in claim 4 which further includes, after said recrystallization-annealing step, a step of dipping said steel sheet in an Al bath to form an Al plating layer on the surface.
- 5 8. The method of production of steel sheet for a hot stamped member as set forth in claim 4 which further includes, after said recrystallization annealing step, a step of dipping said steel sheet in a Zn bath to form a galvanized layer on the surface.
- 10 9. The method of production of steel sheet for a hot stamped member as set forth in claim 4 which further includes, after said recrystallization-annealing step, a step of dipping said steel sheet in a Zn bath to form a galvanized layer on the surface, then further heating to 600°C or less to form a Zn-Fe alloy layer on said surface.

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Fig.1

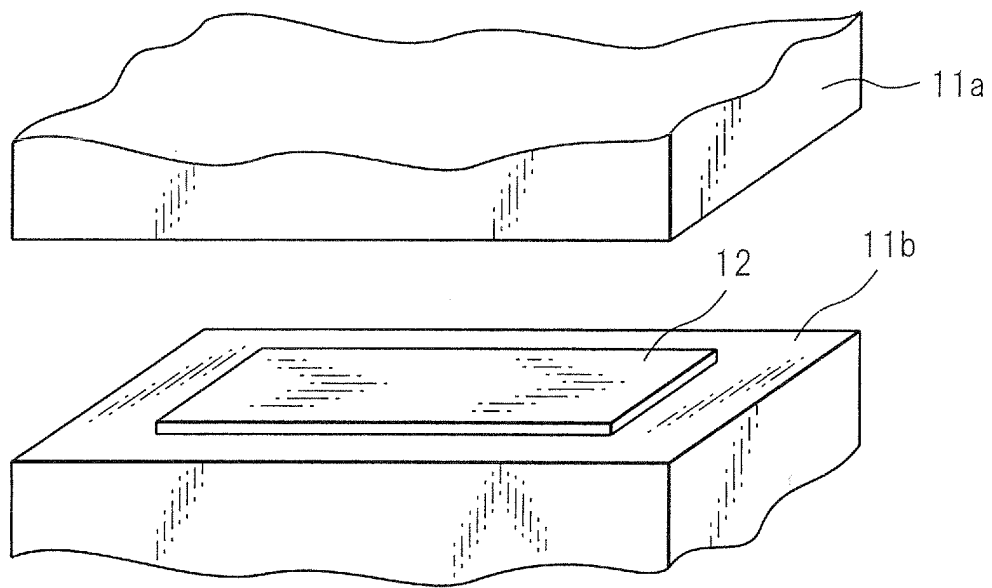


Fig.2

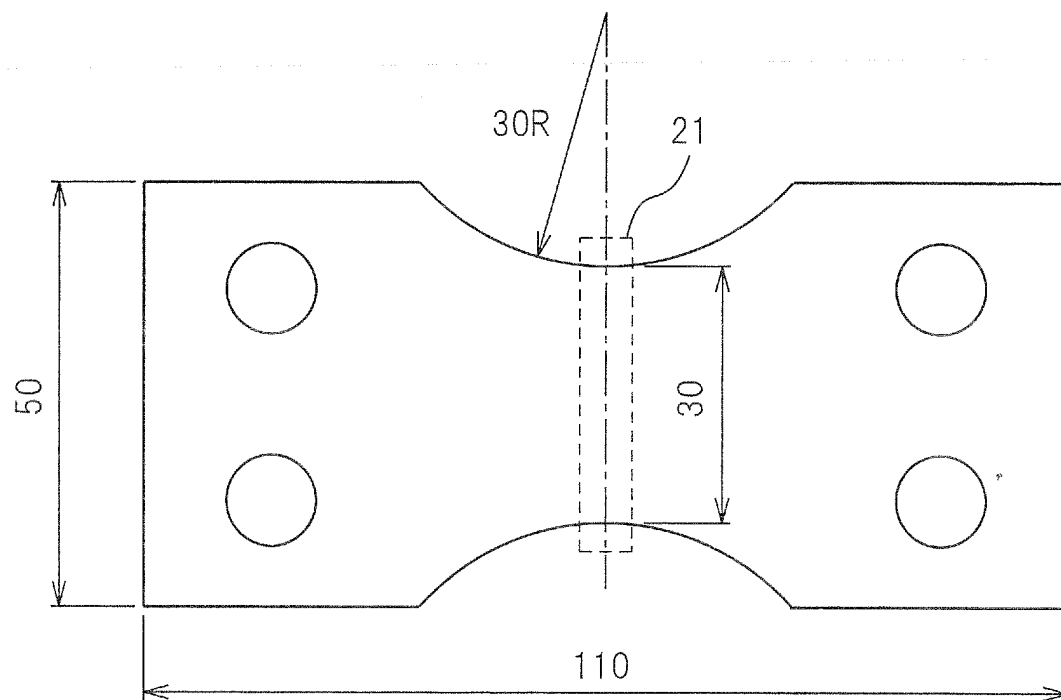


Fig.3

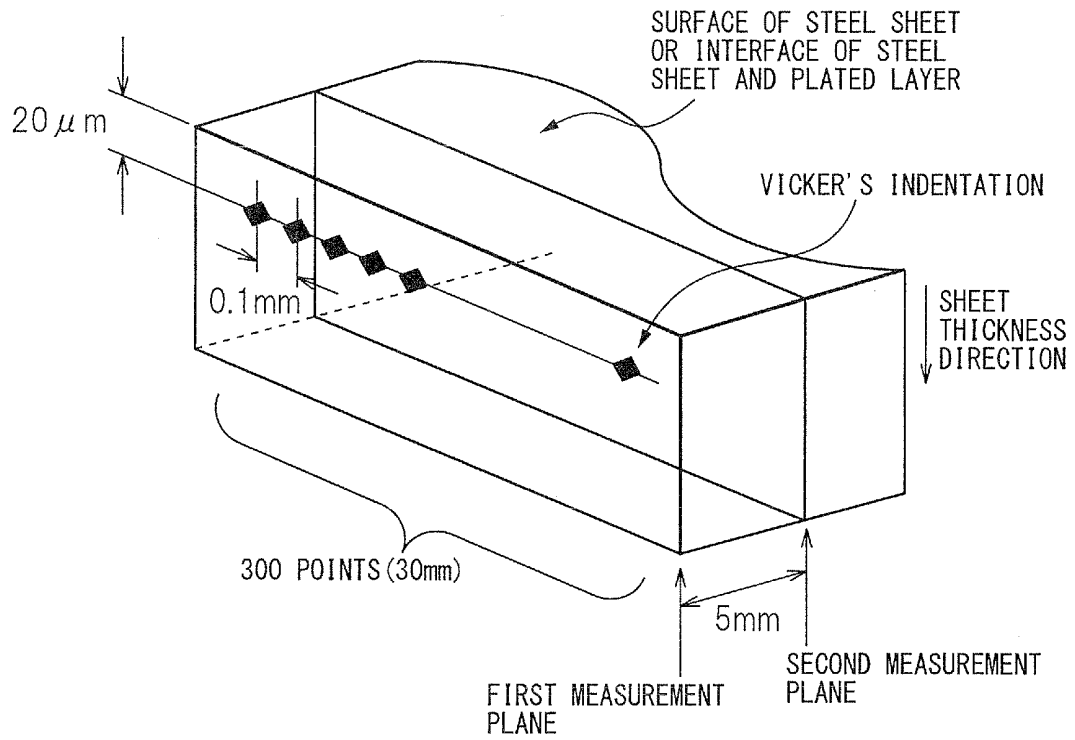


Fig.4

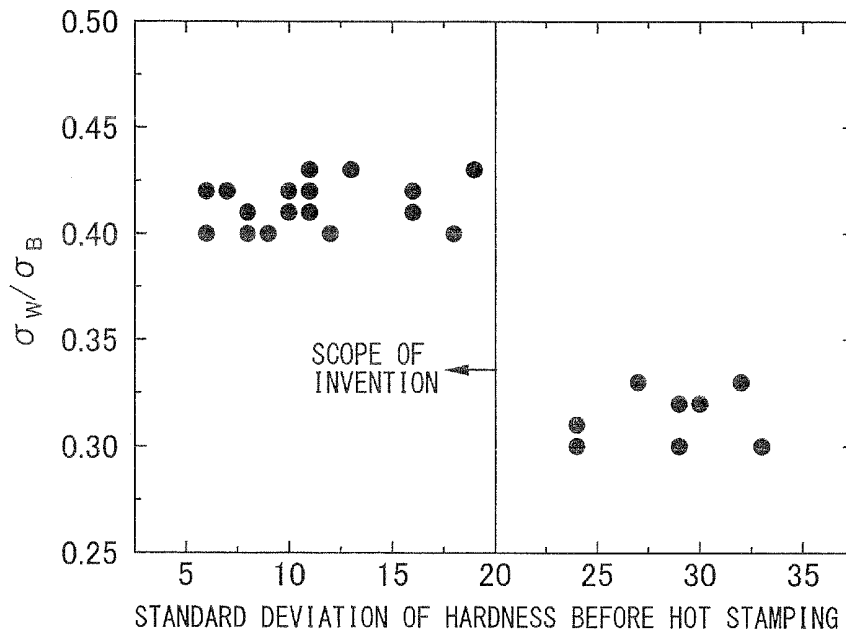


Fig.5

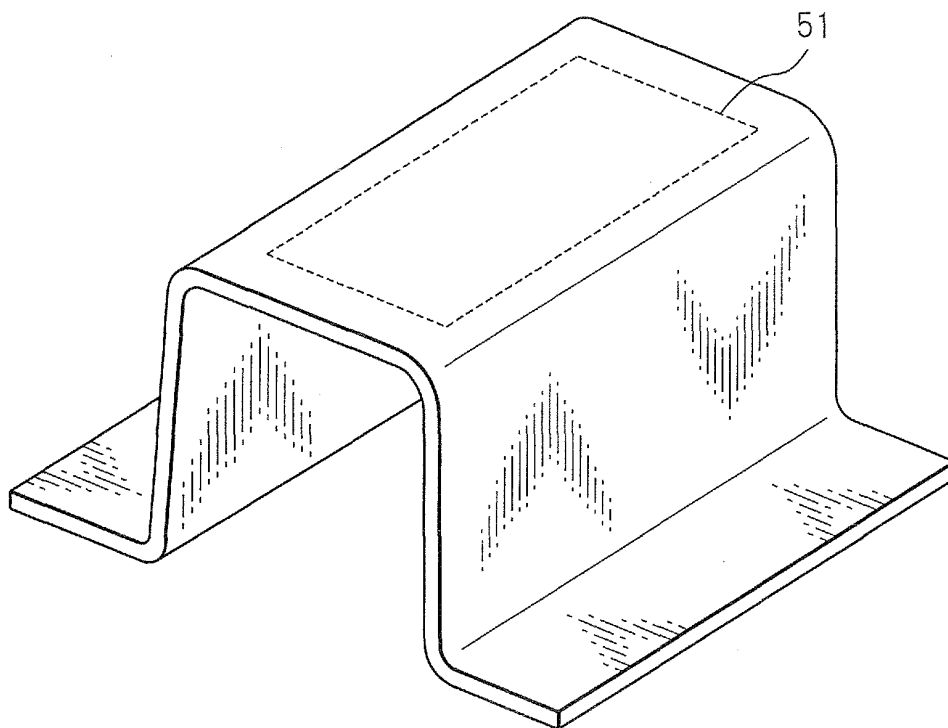
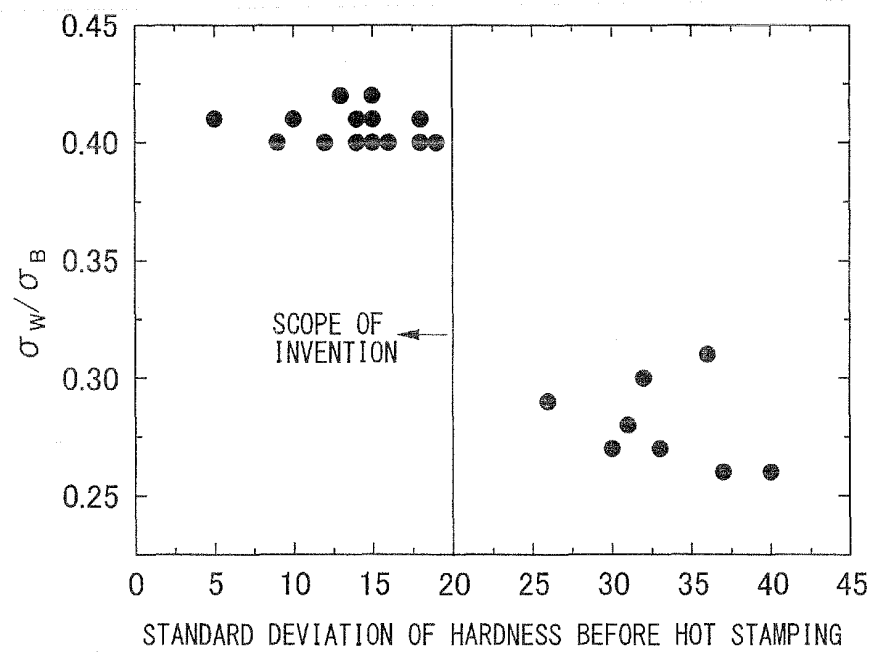


Fig.6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/056917

A. CLASSIFICATION OF SUBJECT MATTER C22C38/00(2006.01)i, C21D1/18(2006.01)i, C21D9/00(2006.01)i, C22C38/06 (2006.01)i, C22C38/58(2006.01)i, C23C2/02(2006.01)i, C23C2/06(2006.01)i, C23C2/12(2006.01)i, C23C2/28(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) C22C38/00-38/60, C21D1/18-1/25, C21D9/00-9/70, C23C2/02, C23C2/06, C23C2/12, C23C2/28 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012 Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2003-147499 A (Sumitomo Metal Industries, Ltd.), 21 May 2003 (21.05.2003), example 2; fig. 1 & US 2004/0166360 A1 & US 2005/0252262 A1 & EP 1439240 A1 & WO 2003/035922 A1 & KR 2006/0090309 A & CN 1575348 A & CN 101144162 A	1-5, 8, 9 6, 7
A	JP 2007-314817 A (Sumitomo Metal Industries, Ltd.), 06 December 2007 (06.12.2007), paragraphs [0007], [0010] (Family: none)	1-9
☒ 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 04 April, 2012 (04.04.12)		Date of mailing of the international search report 17 April, 2012 (17.04.12)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/056917

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006-265583 A (Sumitomo Metal Industries, Ltd.), 05 October 2006 (05.10.2006), paragraphs [0010], [0014] (Family: none)	1-9

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

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