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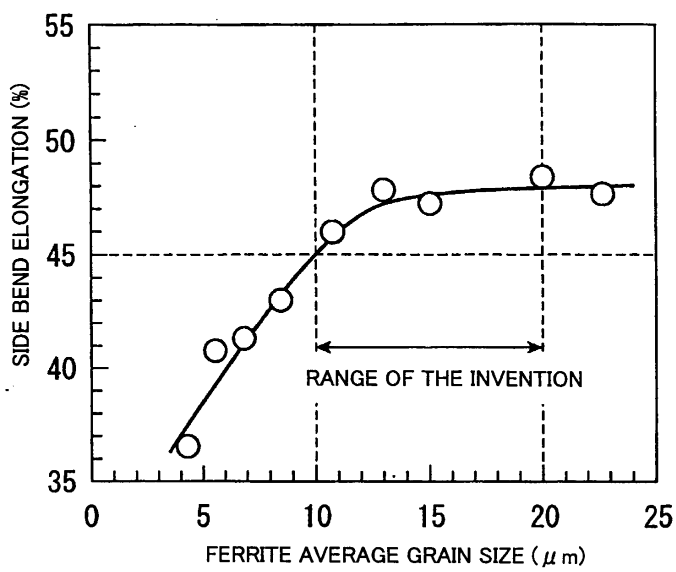
(54) STEEL PLATE HAVING EXCELLENT FINE BLANKING PROCESSABILITY AND METHOD FOR MANUFACTURE THEREOF

(57) A steel sheet excellent in FB performance and also excellent in fabrication performance after FB working and a manufacturing method of the same are provided. The steel sheet is a steel sheet having a composition containing from 0.1 to 0.5% of C, not more than 0.5 % of Si and from 0.2 to 1.5 % of Mn in terms of % by mass, with P and S being adjusted at proper ranges and having a structure having a ferrite having an average grain size of more than 10 μm and less than 20 μm and a cementite present in the ferrite grain having an average particle size of from 0.3 to 1.5 μm. In this way, the steel sheet becomes a steel sheet excellent in FB performance, mold life and performance (side bend elongation) after FB working.

FIG. 1



EP 2 003 220 A1

Description

TECHNICAL FIELD

[0001] The present invention is concerned with a steel sheet suitable for applications to automobile parts or the like and in particular, relates to a steel sheet excellent in fine blanking performance suitable for the uses to which fine blanking working (hereinafter also referred to as "FB working") is applied.

BACKGROUND ART

[0002] In manufacturing complicated mechanical parts, from the viewpoints of an improvement in dimension precision, a reduction in manufacturing process, and the like, it is known that fine blanking working is an extremely advantageous working method as comparing with machining working.

[0003] In usual blanking working, a tool-to-tool clearance is from approximately 5 to 10 % of a thickness of a metal sheet as a material to be blanked. However, the fine blanking working differs from the usual blanking working and is a blanking working method of not only setting up the tool-to-tool clearance extremely small as substantially zero (actually, not more than approximately 2 % of the thickness of the metal sheet as a material to be blanked) but also making a compression stress act on a material in the vicinity of a tool cutting blade. Then, the fine blanking working has the following characteristic features.

(1) The generation of a crack from the tool cutting blade is inhibited, and a fracture surface seen in usual blanking working becomes substantially zero, whereby a smooth worked surface (blanked end surface) in which the worked surface is a substantially 100 % shear surface is obtained.
(2) The dimensional precision is good.
(3) A complicated shape can be blanked by one process.

[0004] However, in the fine blanking working, a working ratio which the material (metal sheet) receives is extremely severe. Also, in the fine blanking working, since the working is carried out at a tool-to-tool clearance of substantially zero, there is involved a problem that a load to a mold becomes excessive so that a mold life is shortened. For that reason, materials to which the fine blanking working is applied are required to not only have excellent fine blanking performance but also prevent a reduction in mold life.

[0005] In response to these requirements, for example, Patent Document 1 proposes a high carbon steel sheet excellent in fine blanking performance, which has a composition containing from 0.15 to 0.90 % by weight of C, not more than 0.4 % by weight of Si and from 0.3 to 1.0 % by weight of Mn, has a microstructure with a cementite having a spheroidization ratio of 80 % or more and an average grain size of from 0.4 to 1.0 μm scattered in a ferrite matrix and has a notch tensile elongation of 20 % or more. According to a technology described in Patent Document 1, it is described that the fine blanking performance is improved and that the mold life is also improved.

[0006] However, the high carbon steel sheet described in Patent Document 1 involved a problem that fabrication performance after the fine blanking working is inferior.

[0007] Also, Patent Document 2 proposes a steel sheet for fine blanking prepared by applying proper hot rolling to a billet containing from 0.08 to 0.19 % of C and proper amounts of Si, Mn and Al and containing from 0.05 to 0.80 % of Cr and from 0.0005 to 0.005 % of B into a steel sheet. It is described that the steel sheet described in Patent Document 2 is a steel sheet which is low in a yield strength, high in an impact value, excellent in fine blanking performance, high in an n-value in a low strain region, excellent in combined formability and excellent in quenching property at short-time rapid heating. However, Patent Document 2 does not show concrete evaluation regarding the fine blanking performance. Also, the steel sheet described in Patent Document 2 involved a problem that fabrication performance after the fine blanking working is inferior.

[0008] Also, Patent Document 3 proposes a high carbon steel sheet excellent in flow forming and fine blanking working, which has a composition containing from 0.15 to 0.45 % of C, with the contents of Si, Mn, P, S, Al and N being adjusted at proper ranges and has a structure having a fractional ratio of (pearlite + cementite) of not more than 10 % and an average grain size of ferrite grain of from 10 to 20 μm. It is described that the high carbon steel sheet described in Patent Document 3 is excellent in fine blanking performance and is improved in mold life in the fine blanking working. However, the high carbon steel sheet described in Patent Document 3 involved a problem that fabrication performance after the fine blanking working is inferior.

[0009] Furthermore, it is hard to say that all of the steel sheets described in Patent Document 1, Patent Document 2 and Patent Document 3 are not provided with satisfactory and thorough fine blanking performance in the fine blanking working under a recent severe working condition. Also, problems that the mold life is not thoroughly improved and that fabrication performance after the fine blanking working is inferior still remained.

[0010] At the beginning, the fine blanking working had been applied to parts to which working is not applied after fine blanking working even among gear parts and the like. However, recently, the application of fine blanking working to automobile parts (for example, reclining parts) tends to expand, and its application to parts which require stretch flanging working, bulging, etc. is investigated. For that reason, steel sheets which are not only excellent in fine blanking performance but also excellent in fabrication performance after fin blanking working in stretch flanging working, bulging, etc. are eagerly desired as automobile parts.

[0011] As a technology for improving stretch flanging workability, there have been made a number of proposals up to date. For example, Patent Document 4 proposes a wear resistant hot rolled steel sheet excellent in stretch flanging property, which has a composition containing from 0.20 to 0.33 % of C, with the contents of Si, Mn, P, S, sol. Al and N being adjusted at proper ranges and further containing from 0.15 to 0.7 % of Cr and has a ferrite-bainite mixed structure which may contain pearlite. In the hot rolled steel sheet described in Patent Document 4, it is described that by taking the foregoing structure, a hole expansion ratio becomes high, whereby the stretch flanging property is improved. Also, Patent Document 5 proposes a high carbon steel sheet excellent in stretch flanging property, which has a composition containing from 0.2 to 0.7 % of C and has a structure in which a cementite average particle size is 0.1 μm or more and less than 1.2 μm and a volume ratio of a cementite-free ferrite grain is not more than 15 %. In the high carbon steel sheet described in Patent Document 5, it is described that the generation of a void on an end surface at the time of blanking is inhibited, that the growth of a crack in hole expansion working can be made slow and that the stretch flanging property is improved.

[0012] Also, Patent Document 6 proposes a high carbon steel sheet excellent in blanking performance and quenching property, which has a composition containing 0.2 % or more of C and has a structure composed mainly of ferrite and a cementite and having a cementite particle size of not more than 0.2 μm and a ferrite grain size of from 0.5 to 1 μm. It is described that according to this, both blanking performance and quenching property which are determined by a burr height and mold life are improved.

Patent Document 1: JP-A-2000-265240
Patent Document 2: JP-A-59-76861
Patent Document 3: JP-A-2001-140037
Patent Document 4: JP-A-9-49065
Patent Document 5: JP-A-2001-214234
Patent Document 6: JP-A-9-316595

DISCLOSURE OF THE INVENTION

[0013] However, all of the technologies described in Patent Document 4 and Patent Document 5 are those made on the assumption that the conventional blanking working is applied but not those made taking into consideration the application of fine blanking working in which the clearance is substantially zero. Accordingly, it is difficult to ensure similar stretch flanging property after the severe fine blanking working, and even when the stretch flanging property can be ensured, there is encountered a problem that the mold life is short.

[0014] Also, in the technology described in Patent Document 6, it is necessary that the ferrite grain size is in the range of from 0.5 to 1 μm; and it is difficult to stably manufacture a steel sheet having such a ferrite grain size on an industrial scale, resulting in a problem that the product yield is reduced.

[0015] In view of the foregoing problems of the conventional technologies, the invention has been made, and an object thereof is to provide a steel sheet excellent in fine blanking performance and also excellent in fabrication performance after fine blanking working and a manufacturing method of the same.

[0016] In order to achieve the foregoing object, the present inventors made extensive and intensive investigations regarding influences of a metallographic structure against fine blanking performance (hereinafter abbreviated as "FB performance"), especially influences against morphology and distribution state of ferrite and a cementite.

[0017] As a result, it has been found that the FB performance, the fabrication performance after FB working and the mold life are closely related with a particle size of a cementite present in a ferrite grain and a ferrite grain size. Then, it has been newly found that when a raw steel material having a composition of a prescribed range is formed into a hot rolled steel sheet having a substantially 100 % pearlite structure by making a finish rolling condition of hot rolling and a condition of subsequent cooling proper, which is then subjected to hot rolling annealing under a proper condition, thereby converting the metallographic structure into a (ferrite + cementite) (granular cementite) structure having a ferrite average grain size of more than 10 μm and less than 20 μm and a cementite average particle size in ferrite grain of from 0.3 to 1.5 μm, the FB performance, the mold life and the fabrication performance (side bend elongation) after FB working are remarkably improved.

[0018] In the FB working, the material is worked in a state of zero clearance and compression stress. For that reason, there may be a possibility that the material is largely deformed, thereby generating a crack during the subject deformation. When a crack is generated, a fracture surface appears on the blanked surface. In order to prevent the generation of a crack, it is said that spheroidization of a cementite is important. However, in the case where the cementite is coarsely present in the ferrite grain, on the assumption that a void is easy to be formed between cementites at the time of large deformation and that the generation of a crack due to the void growth is unavoidable, the present inventors examined the cementite particle size in ferrite grain and the FB performance. Also, with respect to the mold life, the present inventors assumed that when a fine cementite is present in the ferrite grain, wear of a cutting blade is accelerated, leading to a reduction in mold life. Furthermore, in the case where fabrication is applied after the FB working, the present inventors thought that cracks generated at the time of the FB working are connected to each other, leading to a reduction of the molding performance.

[0019] First of all, the experimental results on a basis of which the invention has been made are described.

[0020] A high steel slab (corresponding to S35C) containing 0.34 % of C, 0.2 % of Si and 0.8 % of Mn in terms of % by mass was heated at 1150°C and then subjected to hot rolling consisting of rough rolling of 5 passes and finish rolling of 7 passes, thereby preparing a hot rolled steel sheet having a thickness of 4.2 mm. Incidentally, a total reduction ratio in the finish rolling of hot rolling was changed to 10 to 40 %; a rolling termination temperature was set up at 860°C; a coiling temperature was set up at 600°C; and after the finish rolling, the steel sheet was cooled while changing a cooling rate from 5°C/s to 250°C/s. Incidentally, in the case where cooling (forced cooling) other than air cooling was carried out, a cooling stopping temperature was set up at 650°C. Subsequently, the hot rolled steel sheet was subjected to pickling and then to batch annealing (720°C × 40 h) as hot rolled sheet annealing.

[0021] A metallurgical structure of the steel sheet to which hot rolled sheet annealing had been applied was first observed.

[0022] In the observation of the metallurgical structure, a specimen was collected from the obtained steel sheet; a cross section parallel to a rolling direction of the subject specimen was polished and corroded with nital; and with respect to a position of 1/4 of the sheet thickness, the metallurgical structure was observed by a scanning electron microscope (SEM) and imaged, thereby measuring a ferrite grain size and a cementite particle size in ferrite grain.

[0023] The ferrite grain size and the cementite particle size in ferrite grain were quantified by image analysis processing by using "Image Pro Plus ver. 4.0" which is an image analysis software manufactured by Media Cybernetics, Inc. With respect to the ferrite grain size, an area of each ferrite grain was measured, and a circle-corresponding size was determined from the resulting area and defined as a grain size of each ferrite grain. The thus obtained respective ferrite grain sizes were arithmetically averaged, and its value was defined as a ferrite average grain size of that steel sheet.

[0024] Also, in the imaged structure, a cementite present on the ferrite grain boundary and a cementite present in the ferrite grain were discriminated from each other by means of image analysis; with respect to each cementite present in the ferrite grain, a diameter passing through two points on the periphery of the cementite and a center of gravity of a corresponding oval of the cementite (an oval having the same area as the cementite and having a primary moment and a secondary moment equal to each other) was measured at every 2° to determine a circle-corresponding size, thereby defining it as a grain size of each cementite. The thus obtained respective cementite particle sizes were arithmetically averaged, and its value was defined as a cementite average particle size of that steel sheet. Incidentally, the number of particles of the measured cementite was 3,000 for each.

[0025] Also, a specimen (size: 100 × 80 mm) was collected from the obtained steel sheet and subjected to an FB test. The FB test was carried out by blanking a sample having a size of 60 mm × 40 mm (corner radius R: 10 mm) from the specimen by using a 110t hydraulic press machine under a lubricious condition of a tool-to-tool clearance of 0.060 mm (1.5 % of the sheet thickness) and a working pressure of 8.5 tons. With respect to an end surface (blanked surface) of the blanked sample, a surface roughness (ten-point average roughness Rz) was measured, thereby evaluating the FB performance. Incidentally, with respect to the specimen, in order to eliminate influences of a deviation in sheet thickness against the clearance, the both surfaces were equally ground in advance, thereby regulating the sheet thickness at 4.0 ± 0.010 mm.

[0026] With respect to the measurement of the surface roughness, as illustrated in Fig. 3, in each of four end surfaces (sheet thickness surfaces) other than R parts, a region within a range of from 0.5 mm to 3.9 mm of the surface in the punch side in the sheet thickness direction and 10 mm in parallel to the surface (X direction) was scanned 35 times at a pitch of 100 μm in the sheet thickness direction (t direction) by using a contact probe profilometer, and a surface roughness Rz in each scanning line was measured according to JIS B 0601-1994. Furthermore, with respect to the surface roughness Rz on the measured surface, Rzs in the respective scanning lines were summed up, and an average value thereof was employed. The four end surfaces were measured in the same method as described above, and an average surface roughness Rz ave (μm) defined according to the following expression: Rz ave = (Rz 1 + Rz 2 + Rz 3 + Rz 4)/4 (wherein Rz 1, Rz 2, Rz 3 and Rz 4 each represents Rz on each surface) was computed.

[0027] In general, the case where the appearance of the fracture surface on the blanked surface is not more than 10 % is defined as "excellent in FB performance". However, in the invention, the case where the average surface roughness Rz ave is small as 10 μm or less was defined as "excellent in FB performance".

[0028] Also, the life of the used tool (mold) was evaluated. A surface roughness (ten-point average roughness Rz) of the sample end surface (blanked surface) at the point of time when the number of blanking in the FB working reached

30,000 times was measured in the same manner as described above, thereby evaluating the mold life.

[0029] Also, a specimen (size: 40 mm × 170 mm (rolling direction)) was blanked from the obtained steel sheet by FB working and subjected to a side bend test, thereby evaluating the performance (side bend elongation) after the FB working. The FB working was carried out under a lubricious condition of a tool-to-tool clearance of 0.060 mm (1.5 % of the sheet thickness) and a working pressure of 8.5 tons.

[0030] With respect to the side bend test, a side bend test was carried out in a state of restraining a side surface (sheet surface) of the specimen according to a method of Nagai, et al. (Yoshinori Nagai and Yasutomo Nagai, PK Giho (Press Technical Report), No. 6 (1995), page 14), thereby measuring an elongation at the time of through thickness cracking. An end surface of the specimen in the side of evaluating the elongation was an FB worked surface in the side of a length of 170 mm. Incidentally, gauge marks for evaluating the elongation at the fracture were written on the specimen by marking-off lines with a gauge mark-to-gauge mark distance of 50 mm. The number of test was two of each steel sheet, and an average value of the obtained elongation values was defined as the side bend elongation value.

[0031] The ferrite average grain size and the cementite average particle size in ferrite grain varied depending upon the total reduction ratio in the finish rolling of hot rolling and the average cooling rate after the finish rolling. The obtained results are shown in Figs. 1 and 2.

[0032] Fig. 1 shows a relationship between the ferrite average grain size and the side bend elongation. It is noted from Fig. 1 that when the ferrite average grain size exceeds 10 μm, the side bend elongation exceeds 45 % and exhibits a very satisfactory value, and satisfactory performance after the FB working is revealed. Incidentally, when the ferrite average grain size is 20 μm or more, burrs after the FB working became large, and the FB performance was reduced. Also, Fig. 2 shows a relationship between the cementite average particle size in ferrite grain and the average surface roughness Rz ave on the blanked surface of the FB working in the case where the ferrite average grain size is more than 10 μm and less than 20 μm. It is noted from Fig. 2 that when the cementite average particle size in ferrite grain is not more than 1.5 μm, Rz ave is not more than 10 μm, and satisfactory FB performance is revealed. Incidentally, when the cementite average particle size in ferrite grain is less than 0.3 μm, the average surface roughness on the blanked surface after blanking 30,000 times exceeded 10 μm, and the mold life was reduced.

[0033] As a result of further extensive and intensive investigations on the basis of the foregoing knowledge, the invention has been accomplished. That is, the gist of the invention is as follows.

(1) A steel sheet excellent in fine blanking performance, which is characterized by having a composition containing from 0.1 to 0.5 % of C, not more than 0.5 % of Si, from 0.2 to 1.5 % of Mn, not more than 0.03 % of P and not more than 0.02 % of S in terms of % by mass, with the remainder being Fe and unavoidable impurities and having a structure mainly composed of ferrite and cementites, wherein the foregoing ferrite has an average grain size of exceeding 10 μm and less than 20 μm, and of the foregoing cementites, a cementite present in the ferrite grain has an average particle size of from 0.3 to 1.5 μm.

(2) The steel sheet as set forth in (1), which is characterized in that in addition to the foregoing composition, the composition further contains not more than 0.1 % of Al in terms of % by mass.

(3) The steel sheet as set forth in (1) or (2), which is characterized in that in addition to the foregoing composition, the composition further contains one or two or more members selected from not more than 3.5 % of Cr, not more than 0.7 % of Mo, not more than 3.5 % of Ni, from 0.01 to 0.1 % of Ti and from 0.0005 to 0.005 % of B in terms of % by mass.

(4) A manufacturing method of a steel sheet excellent in fine blanking performance including successively applying hot rolling by heating and rolling a raw steel material to form a hot rolled sheet and hot rolled sheet annealing by applying annealing to the subject hot rolled sheet, which is characterized in that the foregoing raw steel material is a raw steel material having a composition containing from 0.1 to 0.5 % of C, not more than 0.5 % of Si, from 0.2 to 1.5 % of Mn, not more than 0.03 % of P and not more than 0.02 % of S in terms of % by mass, with the remainder being Fe and unavoidable impurities; the foregoing hot rolling is a treatment in which a total reduction ratio in a temperature region of from 800 to 950˚C in finish rolling is set up at 25 % or more, a termination temperature of finish rolling is set up at from 800 to 950˚C, after completion of the subject finish rolling, cooling is carried out at an average cooling rate of 50˚C/s or more and less than 120˚C/s, the subject cooling is stopped at a temperature in the range of from 500 to 700˚C, and coiling is carried out at from 450 to 600˚C; and the foregoing hot rolled sheet annealing is carried out at an annealing temperature of from 600 to 720˚C.

(5) The manufacturing method of a steel sheet as set forth in (4), which is characterized in that in addition to the foregoing composition, the composition further contains not more than 0.1 % of Al in terms of % by mass.

(6) The manufacturing method of a steel sheet as set forth in (4) or (5), which is characterized in that in addition to the foregoing composition, the composition further contains one or two or more members selected from not more than 3.5 % of Cr, not more than 0.7 % of Mo, not more than 3.5 % of Ni, from 0.01 to 0.1 % of Ti and from 0.0005 to 0.005 % of B in terms of % by mass.

[0034] According to the invention, a steel sheet which is not only excellent in FB performance but also excellent in performance (side bend elongation) after the FB working can be easily and cheaply manufactured, thereby giving rise to remarkable effects in view of the industry. Also, according to the invention, there are brought effects that a steel sheet excellent in FB performance is provided; an end surface treatment after the FB working is not necessary; a time of completion of manufacture can be shortened; the productivity is improved; and the manufacturing costs can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035]

Fig. 1 is a graph to show a relationship between a ferrite average grain size and a side bend elongation after FB working.

Fig. 2 is a graph to show a relationship between FB performance (average surface roughness on blanked surface: Rz ave) and a cementite average particle size in ferrite grain.

Fig. 3 is an explanatory view to schematically show a measurement region of surface roughness on a blanked surface after FB working.

BEST MODES FOR CARRYING OUT THE INVENTION

[0036] First of all, the reasons why the composition of the steel sheet of the invention is limited are described. Incidentally, the "% by mass" in the composition is expressed merely as "%" unless otherwise indicated.

C: from 0.1 to 0.5 %

[0037] C is an element influencing the hardness after hot rolling annealing and quenching, and in the invention, C is required to be contained in an amount of 0.1 % or more. When the content of C is less than 0.1%, the hardness required as automobile parts cannot be obtained. On the other hand, since C is contained in a large amount exceeding 0.5 %, the steel sheet becomes hard, an industrially sufficient mold life cannot be ensured. For that reason, the content of C was limited to the range of from 0.1 to 0.5 %.

Si: not more than 0.5 %

[0038] Si is an element not only acting as a deoxidizing agent but also increasing the strength (hardness) due to solution hardening. However, when Si is contained in a large amount exceeding 0.5 %, ferrite becomes hard, thereby reducing the FB performance. Also, when Si is contained in an amount exceeding 0.5 %, a surface defect called as red scale is generated at the hot rolling stage. For that reason, the content of Si was limited to not more than 0.5 %. Incidentally, the content of Si is preferably not more than 0.35 %.

Mn: from 0.2 to 1.5 %

[0039] Mn is an element not only increasing the strength of steel due to solution hardening but also acting effectively in improving the quenching property. In order to obtain such an effect, it is desirable that Mn is contained in an amount of 0.2 % or more. However, when Mn is contained excessively in an amount exceeding 1.5 %, the solution hardening becomes excessively strong so that the ferrite becomes hard, thereby reducing the FB performance. For that reason, the content of Mn was limited to the range of from 0.2 to 1.5 %. Incidentally, the content of Mn is preferably from 0.2 to 1.0 %, and more preferably from 0.6 to 0.9 %.

P: not more than 0.03 %

[0040] Since P segregates on the grain boundary or the like and reduces the performance, in the invention, it is desirable that P is reduced as far as possible. However, the content of P of up to 0.03 % is tolerable. For such a reason, the content of P was limited to not more than 0.03 %. Incidentally, the content of P is preferably not more than 0.02 %.

S: not more than 0.02 %

[0041] S is an element which forms a sulfide such as MnS and exists as an inclusion in the steel, thereby reducing the FB performance, and it is desirable that S is reduced as far as possible. However, the content of S of up to 0.02 % is tolerable. For such a reason, the content of S was limited to not more than 0.02 %. Incidentally, the content of S is preferably not more than 0.01 %.

[0042] The foregoing components are a basic composition. However, in the invention, in addition to the foregoing basic composition, Al and/or one or two or more members selected from Cr, Mo, Ni, Ti and B can be contained.

Al: not more than 0.1 %

[0043] Al is an element not only acting as a deoxidizing agent but also binding with N to form AlN, thereby contributing to prevention of an austenite grain from coarseness. When Al is contained together with B, Al also has an affect for fixing N, thereby preventing a reduction of the content of B effective for improving the quenching property. Such effects become remarkable when the content of Al is 0.02 % or more. However, when the content of Al exceeds 0.1 %, an index of cleanliness of steel is reduced. For that reason, when Al is contained, it is preferable that the content of Al is limited to not more than 0.1 %. Incidentally, the content of Al as an unavoidable impurity is not more than 0.01 %.

[0044] All of Cr, Mo, Ni, Ti and B are an element contributing to an improvement in quenching property and/or an improvement in resistance to temper softening and can be selected and contained as the need arises.

Cr: not more than 3.5 %

[0045] Cr is an element effective for improving the quenching property. In order to obtain such an effect, it is preferable that Cr is contained in an amount of 0.1 % or more. However, when the content of Cr exceeds 3.5 %, not only the FB performance is reduced, but also an excessive increase of the resistance to temper softening is brought. For that reason, when Cr is contained, it is preferable that the content of Cr is limited to not more than 3. 5 %. Incidentally, the content of Cr is more preferably from 0.2 to 1.5 %.

Mo: not more than 0.7 %

[0046] Mo is an element acting to effectively improve the quenching property. In order to obtain such an effect, it is preferable that Mo is contained in an amount of 0.05 % or more. However, when the content of Mo exceeds 0.7 %, the steel becomes hard, thereby reducing the FB performance. For that reason, when Mo is contained, it is preferable that the content of Mo is limited to not more than 0.7 %. Incidentally, the content of Mo is more preferably from 0.1 to 0.3 %.

Ni: not more than 3.5 %

[0047] Ni is an element effective for improving the quenching property. In order to obtain such an effect, it is preferable that Ni is contained in an amount of 0.1 % or more. However, when the content of Ni exceeds 3.5 %, the steel becomes hard, thereby reducing the FB performance. For that reason, when Ni is contained, it is preferable that the content of Ni is limited to not more than 3.5 %. Incidentally, the content of Ni is more preferably from 0.1 to 2.0 %.

Ti: from 0.01 to 0.1 %

[0048] Ti is easy to bind with N to form TiN and is an element effectively acting to prevent coarseness of a γ grain at the time of quenching. Also, when Ti is contained together with B, since Ti reduces N which forms BN, it has an effect for minimizing the addition amount of B necessary for improving the quenching property. In order to obtain such effects, it is required that the content of Ti is 0.01 % or more. On the other hand, when the content of Ti exceeds 0.1 %, the ferrite is subjected to precipitation strengthening due to precipitation of TiC or the like and becomes hard, thereby reducing the mold life. For that reason, when T is contained, it is preferable that the content of Ti is limited to the range of from 0.01 to 0.1 %. Incidentally, the content of Ti is more preferably from 0.015 to 0.08 %.

B: from 0.0005 to 0.005 %

[0049] B is an element which segregates on an austenite grain boundary and when contained in a trace amount, improves the quenching property. In particular, the case where B is compositely added together with Ti is effective. In order to improve the quenching property, it is required that the content of B is 0.0005 % or more. On the other hand, even when B is contained in an amount exceeding 0.005 %, the effect is saturated and an effect that corresponds to the content cannot be expected, and therefore, such is economically disadvantageous. For that reason, when B is contained, it is preferable that the content of B is limited to the range of from 0.0005 to 0.005 %. Incidentally, the content of B is more preferably from 0.0008 to 0.004 %.

[0050] The remainder other than the foregoing components is Fe and unavoidable impurities. Incidentally, as the unavoidable impurities, for example, not more than 0.01 % of N, not more than 0.01 % of O and not more than 0.1 %

of Cu are tolerable.

[0051] Next, the reasons why the structure of the steel sheet of the invention is limited are described.

[0052] The steel sheet of the invention has a structure composed mainly of ferrite and a cementite. The "structure composed mainly of ferrite and a cementite" as referred to herein means a structure in which ferrite and a cementite account for 95 % or more in terms of a volume ratio. That is, though the steel sheet of the invention has a composition made of ferrite and a cementite, other phases than the ferrite and cementite can be tolerated in an amount of up to approximately 5 % in terms of a volume ratio.

[0053] In the steel sheet of the invention, a grain size of the ferrite is more than 10 μm and less than 20 μm in terms of an average grain size. When the ferrite average grain size is not more than 10 μm, the side bend elongation after the FB working is reduced as shown in Fig. 1. While this reason is not elucidated, the present inventors assume that when the ferrite grain size is not more than 10 μm, since a diffusion rate is fast on the ferrite grain boundary and an average particle size of the cementite present on the ferrite grain boundary is easy to become large, a void is generated between the cementites on the ferrite grain boundary due to large deformation at the time of FB working and grows, thereby easily forming cracks; and that the cracks develop at the time of fabrication after the FB working and are united, whereby the side bend elongation after the FB working is reduced. On the other hand, when the ferrite average grain size is 20 μm or more, though the steel sheet is softened so that the mold life is improved, a burr height after the working remarkably increases. For that reason, the ferrite average grain size was limited to more than 10 μm and less than 20 μm. Incidentally, it is preferably from 12 to 18 μm.

[0054] Also, in the steel sheet of the invention, of the cementites, a cementite present in the ferrite grain has an average particle size in the range of from 0.3 to 1.5 μm. When the average particle size of a cementite present in the ferrite grain is less than 0.3 μm, the steel plate becomes hard, whereby the mold life is reduced. On the other hand, where the cementite particle exceeds 1.5 μm and becomes coarse, as shown in Fig. 2, a void is generated between the cementites due to large deformation at the time of FB working and grows to form a crack, a fracture surface is generated so that the roughness of the worked surface (blanked surface) increases, and the FB performance is reduced. For that reason, the cementite average particle size in ferrite grain was limited to the range of from 0.3 to 1.5 μm.

[0055] Next, a preferred manufacturing method of the steel sheet of the invention is described.

[0056] It is preferable that a molten steel having the foregoing composition is molten by a common melting method using a converter or the like and formed into a raw steel material (slab) by a common casting method such as a continuous casting method.

[0057] Subsequently, the obtained raw steel material is subjected to hot rolling to form a hot rolled sheet by heating and rolling.

[0058] The hot rolling is a treatment in which a total reduction ratio in a temperature region of from 800 to 950˚C in finish rolling is set up at 25 % or more, a termination temperature of finish rolling is set up at from 800 to 950˚C, after completion of the finish rolling, cooling is carried out at an average cooling rate of 50˚C/s or more and less than 120˚C/s, the subject cooling is stopped at a temperature in the range of from 500 to 700˚C, and coiling is carried out at from 450 to 600˚C.

[0059] In the hot rolling in the invention, by adjusting the termination temperature of finish rolling and the subsequent cooling condition, a hot rolled steel sheet having a substantially 100 % pearlite structure is obtained. In addition, in the hot rolling in the invention, by regulating the total reduction ratio in a temperature region of from 800 to 950˚C in finish rolling at 25 % or more, after proper hot rolled sheet annealing, a structure having a ferrite average grain size of more than 10 μm and less than 20 μm is obtained.

Total reduction ratio in temperature region of from 800 to 950˚C in finish rolling: 25 % or more

[0060] In the finish rolling of hot rolling, by increasing the reduction ratio, the austenite grain size becomes small; following this, the pearlite grain size after transformation becomes fine; and in the hot rolled sheet annealing, the growth of the ferrite grain is accelerated while applying, as a driving force, high grain boundary energy that the fine pearlite possesses.

[0061] Here, in particular, at high temperatures exceeding 950˚C, since the austenite grain size is easy to become large due to recrystallization, influences of the rolling in a temperature region of not higher than 950˚C are large.

[0062] The pearlite changes into polygonal ferrite and spherical cementite due to hot rolled sheet annealing. In order to make the ferrite formed by this hot rolled sheet annealing have an average grain size of more than 10 μm and less than 20 μm, the total reduction ratio in a temperature region of from 800 to 950˚C in finish rolling is 25 % or more, a value of which is a reduction ratio larger than that in usually performed rolling. When the total reduction ratio in a temperature of from 800 to 950˚C is less than 25 %, the reduction ratio is insufficient, and it becomes to difficult to make the ferrite grain size fall within a desired range. Incidentally, from the viewpoint of a rolling load, it is preferable that an upper limit of the total reduction ratio is not more than 35 %. Incidentally, the total reduction ratio is more preferably from 25 to 33 %.

Termination temperature of finish rolling: from 800 to 950˚C

[0063] When the termination temperature of finish rolling exceeds 950˚C and becomes high, not only a generated scale becomes thick so that the pickling property is reduced, but also a decarburized layer may possibly be formed in the steel sheet surface layer, whereby the ferrite grain size is easy to become coarse. On the other hand, when the termination temperature of finish rolling is lower than 800˚C, an increase in the rolling load becomes remarkable, and an excessive load against a rolling mill becomes problematic. For that reason, it is preferable that the termination temperature of finish rolling is a temperature in the range of from 800 to 950˚C.

Average cooling rate after completion of finish rolling: 50˚C/s or more and less than 120˚C/s

[0064] After completion of the finish rolling, cooling is carried out at an average cooling rate of 50˚C/s or more. Incidentally, the subject average cooling rate is an average cooling rate of from the termination temperature of finish rolling to a stopping temperature of the subject cooling (forced cooling). When the average cooling rate is less than 50˚C/s, cementite-free ferrite is formed during cooling, and the structure after cooling is a heterogeneous structure of (ferrite + pearlite), whereby a homogeneous structure composed of substantially 100 % pearlite cannot be ensured. When the hot rolled sheet structure is a heterogeneous structure of (ferrite + pearlite), the cementite distribution is also heterogeneous, and whatever the subsequent hot rolled sheet annealing is devised, the cementite present in the grain is easy to become coarse. Accordingly, it is preferable that the average cooling rate after completion of the finish rolling is limited to 50˚C/s or more. Incidentally, from the viewpoint of preventing the formation of bainite, it is preferable that the average cooling rate after completion of the finish rolling is less than 120˚C/s. When the average cooling rate is 120˚C/s or more, since the structure is easy to differ between the steel sheet surface layer part and the sheet thickness central part and after the hot rolled sheet annealing, deformability differs between the surface layer part and the sheet thickness central part, the mold lifer, the FB performance and the fabrication performance after the FB working are easy to be reduced. For that reason, it is preferable that the average cooling rate after the finish rolling is 50˚C/s or more and less than 120˚C/s.

Cooling stopping temperature: from 500 to 700˚C

[0065] It is preferable that a temperature at which the foregoing cooling (forced cooling) is stopped is from 500 to 700˚C. When the cooling stopping temperature is lower than 500˚C, there are caused problems in operation such as a problem that hard bainite or martensite is formed, whereby the hot rolled sheet annealing takes a long time; and the generation of a crack at the time of coiling. On the other hand, when the cooling stopping temperature exceeds 700˚C and becomes high, since a ferrite transformation noise is present in the vicinity of 700˚C, ferrite is formed during cooling after stopping of cooling, whereby a homogeneous structure composed of substantially 100 % pearlite cannot be ensured. From these matters, it is preferable that the cooling stopping temperature is limited to a temperature in the range of form 500 to 700˚C. Incidentally, the cooling stopping temperature is more preferably from 500 to 650˚C, and further preferably from 500 to 600˚C.

[0066] After stopping the cooling, the hot rolled sheet is immediately coiled in a coil state.

Coiling temperature: from 450 to 600˚C

[0067] When the coiling temperature is lower than 450˚C, a crack is formed in the steel sheet at the time of coiling, resulting in a problem in operation. On the other hand, where the coiling temperature exceeds 600˚C, there is a problem that ferrite is formed during the coiling.

[0068] Incidentally, the coiling temperature is preferably from 500 to 600˚C.

[0069] The thus obtained hot rolled sheet (hot rolled steel sheet) is then subjected to removal of an oxidized scale of the surface by pickling or shot blasting and subsequently to hot rolled sheet annealing at an annealing temperature of from 600 to 720˚C. By applying proper hot rolled sheet annealing to the hot rolled sheet having a substantially 100 % pearlite structure, the spheroidization of a cementite is accelerated, whereby not only the ferrite grain size is adjusted at a desired range, but also the cementite particle size in ferrite grain can be adjusted at a desired range.

Annealing temperature of hot rolled sheet annealing: from 600 to 720˚C

[0070] When the annealing temperature is lower than 600˚C, the cementite average particle size in ferrite grain is less than 0.3 μm. On the other hand, the annealing temperature exceeds 720˚C and becomes high, the cementite particle size in ferrite grain exceeds 1.5 μm, and the FB performance is reduced. Incidentally, though a holding time of the hot rolled sheet annealing is not required to be particularly limited, in order to adjust the cementite particle range at a desired range, it is preferable that the holding time is 8 hours or more. Also, when it exceeds 80 hours, since the ferrite grain becomes excessively coarse and the cementite average particle size in ferrite grain may possibly exceed 1.5 μm, the holding time is preferably not more than 80 hours.

EXAMPLES

[0071] A raw steel material (slab) having a composition shown in Table 1 was used as a starting material. Such a raw material was heated at a heating temperature shown in Table 2, and a hot rolled sheet having a thickness of 4.2 mm was then prepared under a hot rolling condition shown in Table 2.

[0072] With respect to the hot rolling condition, the total reduction ratio in a temperature region of from 800˚C to 950˚C in finish rolling, the rolling termination temperature of finish rolling, the average cooling rate in cooling after completion of the finish rolling, the cooling stopping temperature and the coiling temperature were varied.

[0073] Such a hot rolled sheet was then subjected to batch annealing and pickling. The obtained steel sheet was evaluated with respect to structure observation, FB performance and performance (side bend elongation) after FB working. The test methods are as follows.

(1) Structure observation:

[0074] A specimen for structure observation was collected from the obtained steel sheet. A cross section parallel to a rolling direction of the specimen was polished and corroded with nital; and with respect to a position of 1/4 of the sheet thickness, a metallurgical structure was observed (field number: 30 places) by a scanning electron microscope (SEM) (magnification, ferrite: 1,000 times, cementite: 3,000 times); a volume ratio of ferrite and a cementite, a ferrite grain size and a cementite particle size in ferrite grain were measured by image analysis processing by using "Image Pro Plus ver. 4.0" which is an image analysis software manufactured by Media Cybernetics, Inc.

[0075] With respect to the volume ratio of ferrite and a cementite, the metallurgical structure was observed (field number: 30 places) by SEM (magnification: 3,000 times); an area ratio obtained by dividing an area resulting from summing up an area of ferrite excluding a cementite and an area of a cementite by a total field area; and this value was judged as a volume ratio of ferrite and a cementite. With respect to the ferrite grain size, an area of each ferrite grain was measured, and a circle-corresponding size was determined from the resulting area and defined as a grain size of each ferrite grain. The thus obtained respective ferrite grain sizes were arithmetically averaged, and its value was defined as a ferrite average grain size of that steel sheet. Incidentally, the measured area ratio was determined with respective to 500 grains for each.

[0076] With respect to the cementite particle size in ferrite grain, a cementite present in the ferrite grain was discriminated in each field (field number: 30 places) of the observation of a metallurgical structure (magnification: 3,000 times); with respect to each cementite present in the ferrite grain, a diameter passing through two points on the periphery of the cementite and a center of gravity of a corresponding oval of the cementite (an oval having the same area as the cementite and having a primary moment and a secondary moment equal to each other) was measured at every 2˚ to determine a circle-corresponding size, thereby defining it as a particle size of each cementite. The thus obtained respective cementite particle sizes were averaged, and its value was defined as a cementite average particle size in ferrite grain. Incidentally, the number of particles of the measured cementite was 3,000 for each.

(2) FB performance:

[0077] A specimen (size: 100 $\times$ 80 mm) was collected from the obtained steel sheet and subjected to an FB test. The FB test was carried out by blanking a sample having a size of 60 mm $\times$ 40 mm (corner radius R: 10 mm) from the specimen by using a 110t hydraulic press machine under a lubricious condition of a tool-to-tool clearance of 0.060 mm (1. 5 % of the sheet thickness) and a working pressure of 8.5 tons. With respect to an end surface (blanked surface) of the blanked sample, a surface roughness (ten-point average roughness Rz) was measured, thereby evaluating the FB performance. Incidentally, with respect to the specimen, in order to eliminate influences of a deviation in sheet thickness against the clearance, the both surfaces were equally ground in advance, thereby regulating the sheet thickness at 4.0 $\pm$ 0.010 mm.

[0078] With respect to the measurement of the surface roughness, as illustrated in Fig. 3, in each of four end surfaces (sheet thickness surfaces) other than R parts, a region within a range of from 0.5 mm to 3.9 mm of the surface in the punch side in the sheet thickness direction and 10 mm in parallel to the surface (X direction) was scanned 35 times at a pitch of 100 μm in the sheet thickness direction (t direction) by using a contact probe profilometer, and a surface roughness Rz in each scanning line was measured according to JIS B0601-1994. Furthermore, with respect to the surface roughness Rz on the measured surface, Rzs in the respective scanning lines were summed up, and an average value thereof was employed. The four end surfaces were measured in the same method as described above, and an average surface roughness Rz ave (μm) defined according to the following expression was computed, thereby evaluating the FB performance:

$$Rz\ ave = (Rz\ 1 + Rz\ 2 + Rz\ 3 + Rz\ 4)/4$$

(wherein Rz 1, Rz 2, Rz 3 and Rz 4 each represents Rz on each surface.)

[0079] Incidentally, as described previously, in the invention, the case where the average surface roughness Rz ave is small as 10 μm or less was defined as "excellent in FB performance".

[0080] Also, the presence or absence of the generation of a large burr (burr height) which is of a problem as the FB working was observed.

[0081] Also, the life of the used tool (mold) was evaluated. A surface roughness (ten-point average roughness Rz) of the sample end surface (blanked surface) at the point of time when the number of blanking in the FB working reached 30,000 times was measured, thereby evaluating the mold life. Incidentally, the measurement method the surface roughness was the same as described above. The case where the average surface roughness Rz ave of the sample end surface is not more than 10 μm is defined as "○"; the case where it is more than 10 μm and not more than 16 μm was defined as "Δ"; and the case where it is more than 16 μm was defined as "×".

(3) Performance (side bend elongation) after FB working:

[0082] A specimen (size: 40 mm × 170 mm (rolling direction)) was blanked from the obtained steel sheet by FB working and subjected to a side bend test, thereby evaluating the performance (side bend elongation) after the FB working.

[0083] Incidentally, in order to eliminate influences of a deviation in sheet thickness against the clearance, the both surfaces were equally ground in advance, thereby regulating the sheet thickness at 4.0 ± 0.010 mm. The FB working was carried out under a lubricious condition of a tool-to-tool clearance of 0.060 mm (1.5 % of the sheet thickness) and a working pressure of 8.5 tons.

[0084] With respect to the side bend test, a side bend test was carried out in a state of restraining a side surface (sheet surface) of the specimen according to a method of Nagai, et al. (Yoshinori Nagai and Yasutomo Nagai, PK Giho (Press Technical Report), No. 6 (1995), page 14), thereby measuring an elongation at the time of through thickness cracking. An end surface of the specimen in the side of evaluating the elongation was an FB worked surface in the side of a length of 170 mm. Incidentally, gauge marks for evaluating the elongation at the fracture were written on the specimen by marking-off lines with a gauge mark-to-gauge mark distance of 50 mm. The number of test was two of each steel sheet, and an average value of the obtained elongation values was defined as the side bend elongation value. The performance (side bend elongation) after the FB working was evaluated such that the case where the side bend elongation value is 45 % or more is defined as "O"; and that the case where it is less than 45 % is defined as "×".

[0085] The obtained results are shown in Table 3.

[0086] In all of the examples of the invention, the average surface roughness Rz ave on the blanked surface is not more than 10 μm; the FB performance is excellent; the blanked surface at the time of 30,000 times in blanking number is smooth (evaluation: ○); and a reduction in mold life is not acknowledged. Also, the examples of the invention are excellent in the side bend elongation (Performance) after the FB working. Incidentally, in all of the examples of the invention, it was confirmed that the sum of volume ratio of the ferrite and cementite is 95 % or more, thereby forming a structure composed mainly of ferrite and a cementite. On the other hand, in the examples of comparison falling outside the scope of the invention, the average surface roughness Rz ave on the blanked surface exceeds 10 μm and becomes coarse, whereby the FB performance is reduced; or a large burr is generated at the time of the FB working; or the mold life is reduced; the side bend elongation (performance) after the FB working is reduced; or all of the FB performance, the mold life and the side bend elongation (performance) after the FB working are reduced.

Table 1

Steel No.	Chemical components (% by mass)											
	C	Si	Mn	P	S	Al	N	Cr	Mo	Ni	Ti	B
A	0.15	0.19	0.65	0.014	0.0041	-	0.0066	0.94	0.16	-	-	-
B	0.29	0.03	0.51	0.013	0.0030	-	0.0043	0.23	-	-	0.015	0.0024
C	0.35	0.20	0.71	0.013	0.0035	-	0.0029	-	-	-	-	-
D	0.35	0.02	0.55	0.009	0.0032	-	0.0036	0.21	-	-	0.015	0.0024
E	0.49	0.19	0.73	0.011	0.0042	-	0.0032	-	-	-	-	-
F	0.46	0.19	0.76	0.014	0.0050	-	0.0030	-	-	-	-	-

(continued)

Steel No.	Chemical components (% by mass)											
	C	Si	Mn	P	S	Al	N	Cr	Mo	Ni	Ti	B
G	0.35	0.22	0.72	0.012	0.0037	-	0.0039	0.98	0.17	-	-	-
H	0.17	0.02	0.72	0.021	0.0035	-	0.0033	-	-	-	-	-
I	0.11	0.02	1.42	0.015	0.0038	-	0.0029	-	-	-	-	-
J	0.21	0.20	0.71	0.016	0.0045	-	0.0042	1.02	-	-	-	-
K	0.19	0.24	0.76	0.015	0.0037	-	0.0039	0.48	0.17	0.46	-	-
L	0.34	0.21	0.74	0.015	0.0040	0.035	0.0029	-	-	-	-	-
M	0.23	0.19	0.73	0.013	0.0046	0.028	0.0038	0.80	0.26	1.19	0.02	0.0018
N	0.25	0.23	0.69	0.015	0.0031	-	0.0027	0.91	0.25	-	0.02	0.0024
O	0.22	0.20	0.75	0.014	0.0050	-	0.0033	-	-	1.43	-	-
P	0.19	<u>0.69</u>	0.73	0.016	0.0033	-	0.0040	-	-	-	-	-
Q	0.36	0.21	<u>1.69</u>	0.013	0.0059	-	0.0048	-	-	-	-	-

Table 2

Steel plate No.	Steel No.	Hot rolling condition						Annealing		Remark
		Heating temperature (˚C)	Total reduction ratio* (%)	Termination temperature of finish rolling (˚C)	Average cooling rate (˚C/s)	Cooling stopping temperature (˚C)	Coiling temperature (˚C)	Annealing temperature (˚C)	Annealing time (hr)	
1	A	1150	33	850	115	570	550	720	40	Invention
2	A	1200	27	900	100	660	580	710	40	Invention
3	B	1170	29	865	90	690	590	715	30	Invention
4	B	1220	31	840	105	630	570	710	30	Invention
5	C	1200	28	880	75	550	540	720	40	Invention
6	C	1100	35	850	115	620	550	690	40	Invention
7	D	1210	29	885	110	560	530	720	50	Invention
8	D	1200	27	890	65	680	580	690	30	Invention
9	E	1150	28	855	90	520	470	680	40	Invention
10	E	1200	26	860	75	580	560	710	35	Invention
11	F	1170	27	850	80	550	520	720	60	Invention
12	F	1220	29	835	100	620	490	700	40	Invention
13	G	1150	25	870	115	570	530	720	50	Invention
14	G	1170	28	885	65	500	460	690	40	Invention
15	H	1200	26	925	85	680	580	720	30	Invention
16	H	1210	27	890	110	510	490	680	30	Invention
17	I	1150	28	860	70	620	530	710	50	Invention
18	I	1170	26	880	115	660	510	700	30	Invention
19	J	1200	28	875	95	580	560	720	40	Invention
20	J	1150	26	895	80	680	570	710	30	Invention
21	K	1250	27	910	75	670	580	710	40	Invention
22	K	1150	32	880	100	540	540	700	50	Invention

(continued)

Steel plate No.	Steel No.	Hot rolling condition						Annealing		Remark
		Heating temperature (˚C)	Total reduction ratio* (%)	Termination temperature of finish rolling (˚C)	Average cooling rate (˚C/s)	Cooling stopping temperature (˚C)	Coiling temperature (˚C)	Annealing temperature (˚C)	Annealing time (hr)	
23	A	1210	38	790	75	530	520	710	30	Comparison
24	A	1200	21	880	95	690	680	700	40	Comparison
25	B	1200	27	880	60	720	710	720	40	Comparison
26	B	1170	26	960	115	610	520	680	40	Comparison
27	C	1210	29	855	15	660	640	710	30	Comparison
28	C	1250	22	870	90	600	565	720	30	Comparison
29	D	1200	28	755	85	620	610	700	50	Comparison
30	D	1190	27	890	150	470	460	715	40	Comparison
31	E	1180	30	835	60	680	560	740	30	Comparison
32	E	1200	31	820	110	600	470	590	30	Comparison
33	F	1200	19	905	80	630	610	720	40	Comparison
34	F	1230	26	885	75	730	720	710	40	Comparison
35	G	1200	35	750	85	550	525	700	30	Comparison
36	G	1180	27	860	135	670	640	720	30	Comparison
37	H	1180	25	905	40	710	670	690	40	Comparison
38	H	1200	27	970	90	570	520	710	30	Comparison
39	I	1210	26	905	85	510	405	-	-	Comparison**
40	I	1190	17	855	100	600	560	580	40	Comparison
41	J	1190	28	880	70	420	340	-	-	Comparison**
42	J	1210	29	840	140	710	550	720	40	Comparison
43	K	1170	20	780	115	620	570	700	40	Comparison
44	K	1200	33	780	65	640	605	690	50	Comparison

(continued)

Steel plate No.	Steel No.	Hot rolling condition						Annealing		Remark
		Heating temperature (˚C)	Total reduction ratio* (%)	Termination temperature of finish rolling (˚C)	Average cooling rate (˚C/s)	Cooling stopping temperature (˚C)	Coiling temperature (˚C)	Annealing temperature (˚C)	Annealing time (hr)	
45	L	1210	27	850	55	680	590	710	30	Invention
46	M	1230	26	880	70	660	490	680	30	Invention
47	N	1200	27	860	85	600	460	720	30	Invention
48	O	1220	26	850	100	510	510	700	40	Invention
49	P	1230	28	880	110	630	600	710	30	Comparison
50	Q	1200	26	890	85	600	590	700	50	Comparison

*) Total reduction ratio at from 800 to 950˚C in finish rolling
**) A crack was generated at the time of coiling.

Table 3

Steel plate No.	Steel No.	Ferrite average grain size (μm)	Cementite average particle size in ferrite grain (μm)	FB performance		Performance after FB working		Remark
				Rz ave (μm)	Mold life	Side bend elongation (%)	Evaluation	
1	A	16.2	0.56	6	○	50.4	○	Invention
2	A	17.9	0.83	8	○	47.6	○	Invention
3	B	18.4	0.84	9	○	46.1	○	Invention
4	B	16.8	0.68	6	○	48.3	○	Invention
5	C	17.3	0.45	5	○	48.5	○	Invention
6	C	16.2	0.79	8	○	47.2	○	Invention
7	D	16.7	0.59	5	○	49.7	○	Invention
8	D	18.1	0.44	10	○	46.7	○	Invention
9	E	15.7	0.61	8	○	47.3	○	Invention
10	E	12.5	0.32	7	○	47.8	○	Invention
11	F	17.4	0.86	6	○	48.6	○	Invention
12	F	16.3	0.75	8	○	47.5	○	Invention
13	G	14.7	0.80	5	○	52.2	○	Invention
14	G	11.2	0.46	8	○	45.3	○	Invention
15	H	18.3	0.84	9	○	46.6	○	Invention
16	H	14.7	0.63	7	○	49.0	○	Invention
17	I	12.9	0.85	6	○	48.4	○	Invention
18	I	15.9	0.37	8	○	47.5	○	Invention
19	J	14.3	0.66	4	○	49.9	○	Invention
20	J	19.6	0.41	9	○	47.1	○	Invention
21	K	18.8	0.38	8	○	46.5	○	Invention
22	K	16.6	0.70	5	○	51.8	○	Invention
23	A	8.4	0.21	16	×	42.9	×	Comparison
24	A	9.1	0.41	9	Δ	43.7	×	Comparison
25	B	13.4	1.63	19	×	45.2	○	Comparison
26	B	22.0	0.57	9	○	47.0	○	Comparison***
27	C	11.5	1.56	17	×	45.5	○	Comparison
28	C	7.3	0.44	8	○	38.9	×	Comparison
29	D	11.9	1.58	18	×	46.1	○	Comparison
30	D	23.7	0.23	19	×	45.5	○	Comparison***
31	E	12.6	1.71	22	×	46.8	○	Comparison
32	E	13.5	0.20	24	×	45.3	○	Comparison
33	F	7.4	0.26	17	×	39.7	×	Comparison
34	F	14.2	1.55	19	×	47.6	○	Comparison

(continued)

Steel plate No.	Steel No.	Ferrite average grain size (μm)	Cementite average particle size in ferrite grain (μm)	FB performance		Performance after FB working		Remark
				Rz ave (μm)	Mold life	Side bend elongation (%)	Evaluation	
35	G	15.3	1.65	17	×	46.4	○	Comparison
36	G	25.6	0.22	20	×	45.2	○	Comparison***
37	H	21.0	1.57	16	Δ	46.7	○	Comparison***
38	H	23.2	0.68	8	Δ	46.1	○	Comparison***
39	I	-	-	-	-	-	-	Comparison**
40	I	8.8	0.19	18	×	38.2	×	Comparison
41	J	-	-	-	-	-	-	Comparison**
42	J	27.4	0.23	23	×	45.8	○	Comparison***
43	K	9.3	0.22	21	×	42.9	×	Comparison
44	K	13.4	1.60	19	×	46.0	○	Comparison
45	L	11.7	0.95	8	○	46.3	○	Invention
46	M	13.9	0.40	7	○	48.4	○	Invention
47	N	15.4	1.45	7	○	47.5	○	Invention
48	O	12.6	1.09	7	○	47.8	○	Invention
49	P	13.3	0.72	16	Δ	38.2	×	Comparison
50	Q	11.2	0.53	14	Δ	35.7	×	Comparison
) A Crack was generated at the time of coiling. *) A burr was generated.								

Claims

1. A steel sheet excellent in fine blanking performance, which is **characterized by** having a composition containing from 0.1 to 0.5 % of C, not more than 0.5 % of Si, from 0.2 to 1.5 % of Mn, not more than 0.03 % of P and not more than 0.02 % of S in terms of % by mass, with the remainder being Fe and unavoidable impurities and having a structure mainly composed of ferrite and cementites, wherein said ferrite has an average grain size of exceeding 10 μm and less than 20 μm, and of said cementites, a cementite present in the ferrite grain has an average particle size of from 0.3 to 1.5 μm.

2. The steel sheet according to claim 1, which is **characterized in that** in addition to said composition, the composition further contains not more than 0.1 % of Al in terms of % by mass.

3. The steel sheet according to claims 1 or 2, which is **characterized in that** in addition to said composition, the composition further contains one or two or more members selected from not more than 3.5 % of Cr, not more than 0.7 % of Mo, not more than 3.5 % of Ni, from 0.01 to 0.1 % of Ti and from 0.0005 to 0.005 % of B in terms of % by mass.

4. A manufacturing method of a steel sheet excellent in fine blanking performance including successively applying hot rolling by heating and rolling a raw steel material to form a hot rolled sheet and hot rolled sheet annealing by applying annealing to the hot rolled sheet, which is **characterized in that** said raw steel material is a raw steel material having a composition containing from 0.1 to 0.5 % of C, not more than 0.5 % of Si, from 0.2 to 1.5 % of Mn, not more than 0.03 % of P and not more than 0.02 % of S in terms of % by mass, with the remainder being Fe and unavoidable impurities; said hot rolling is a treatment in which a total reduction ratio in a temperature region of from 800 to 950˚C in finish rolling is set up at 25 % or more, a termination temperature of finish rolling is set up at from 800 to 950˚C, after completion of the finish rolling, cooling is carried out at an average cooling rate of 50˚C/s or more and less than 120˚C/s, the cooling is stopped at a temperature in the range of from 500 to 700˚C, and coiling is carried out at from 450 to 600˚C; and said hot rolled sheet annealing is carried out at an annealing temperature of from 600 to 720˚C.

5. The manufacturing method of a steel sheet according to claim 4, which is **characterized in that** in addition to said composition, the composition further contains not more than 0.1 % of Al in terms of % by mass.

6. The manufacturing method of a steel sheet according to claim 4 or 5, which is **characterized in that in** addition to said composition, the composition further contains one or two or more members selected from not more than 3.5 % of Cr, not more than 0.7 % of Mo, not more than 3.5 % of Ni, from 0.01 to 0.1 % of Ti and from 0.0005 to 0.005 % of B in terms of % by mass.

FIG. 1

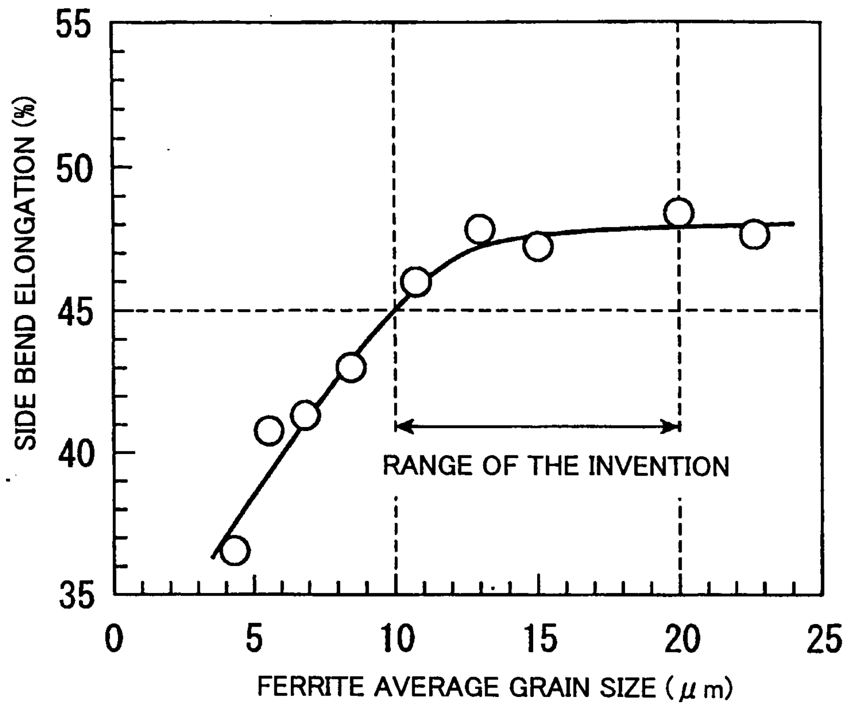

55
50
45
40
35
SIDE BEND ELONGATION (%)
0
5
10
15
20
25
RANGE OF THE INVENTION
FERRITE AVERAGE GRAIN SIZE (μ m)

FIG. 2

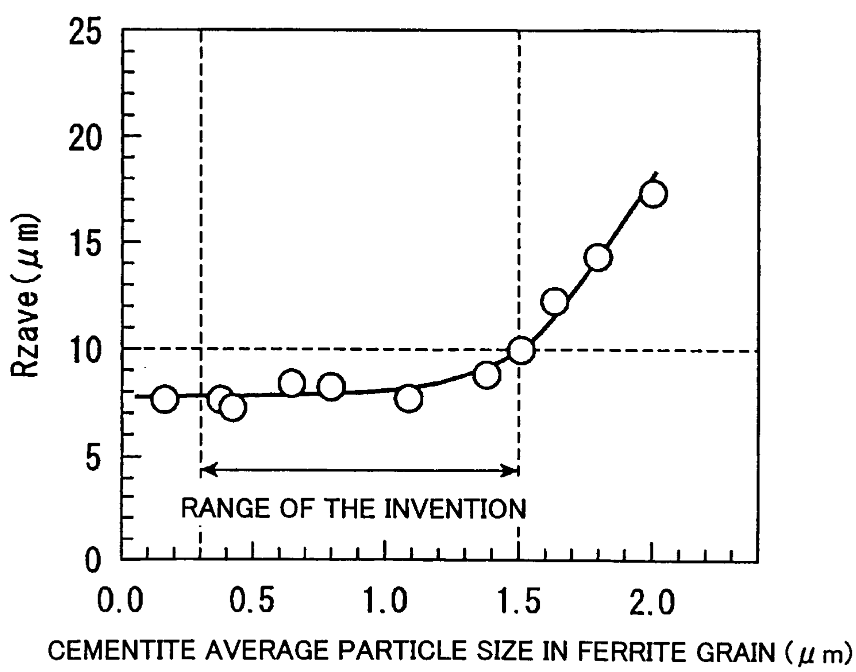
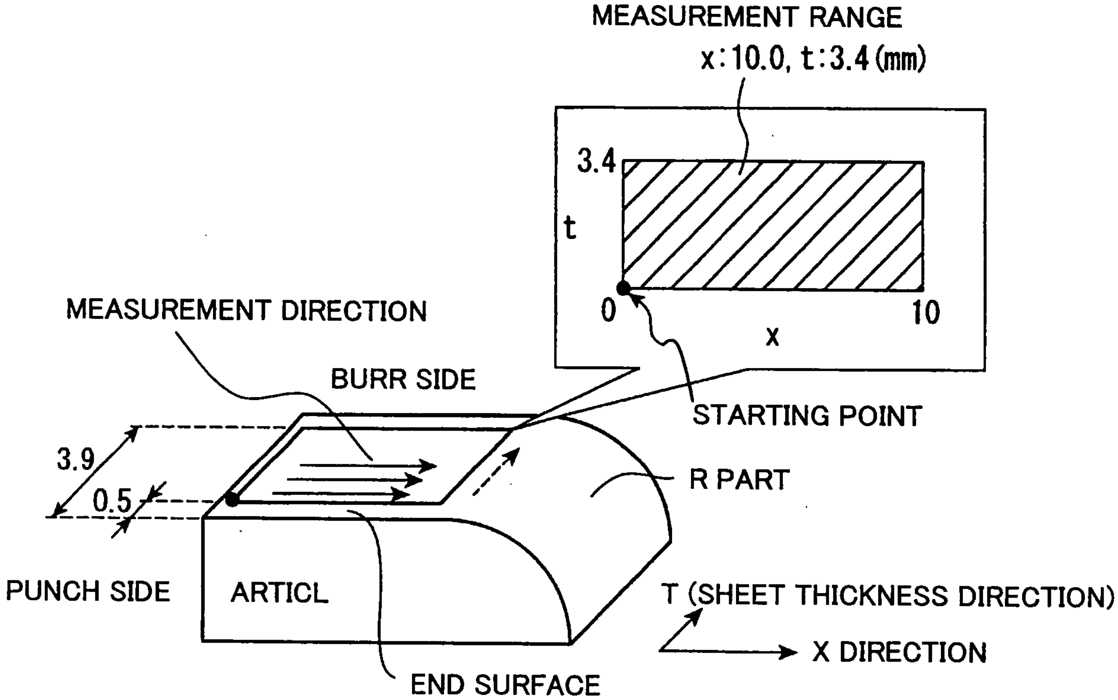

25
20
15
10
5
0
Rzave (μ m)
0.0
0.5
1.0
1.5
2.0
RANGE OF THE INVENTION
CEMENTITE AVERAGE PARTICLE SIZE IN FERRITE GRAIN (μ m)

FIG. 3


MEASUREMENT RANGE
x:10.0, t:3.4(mm)
3.4
t
0
10
x
STARTING POINT
MEASUREMENT DIRECTION
BURR SIDE
3.9
0.5
R PART
PUNCH SIDE
ARTICL
T (SHEET THICKNESS DIRECTION)
X DIRECTION
END SURFACE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/051843

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *C21D9/46*(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, C21D9/46

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	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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.
A	JP 2000-265240 A (Nisshin Steel Co., Ltd.), 26 September, 2000 (26.09.00), Claims (Family: none)	1-6
A	JP 2001-140037 A (Nippon Steel Corp.), 22 May, 2001 (22.05.01), Claims (Family: none)	1-6
A	JP 55-50427 A (Kawasaki Steel Corp.), 12 April, 1980 (12.04.80), Claims (Family: none)	1-6

☒ 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

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"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	Date of mailing of the international search report
13 March, 2007 (13.03.07)	20 March, 2007 (20.03.07)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/051843

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 8-295927 A (Nisshin Steel Co., Ltd.), 12 November, 1996 (12.11.96), Claims (Family: none)	1-6
A	JP 5-339676 A (Nippon Steel Corp.), 21 December, 1993 (21.12.93), Claims (Family: none)	1-6
A	JP S55-85626 A (Nippon Steel Corp.), 27 June, 1980 (27.06.80), Claims (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2000265240 A **[0012]**
- JP 59076861 A **[0012]**
- JP 2001140037 A **[0012]**
- JP 9049065 A **[0012]**
- JP 2001214234 A **[0012]**
- JP 9316595 A **[0012]**

Non-patent literature cited in the description

- Yoshinori Nagai and Yasutomo Nagai. **NAGAI et al.** PK Giho. Press Technical Report, 1995, 14 **[0030] [0084]**