



(11) **EP 1 980 635 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

- (43) Date of publication: **15.10.2008 Bulletin 2008/42**
- (51) Int Cl.: **C22C 38/00 (2006.01) C21D 9/46 (2006.01)**
- (21) Application number: **07713798.2**
- (86) International application number: **PCT/JP2007/051835**
- (22) Date of filing: **29.01.2007**
- (87) International publication number: **WO 2007/088985 (09.08.2007 Gazette 2007/32)**

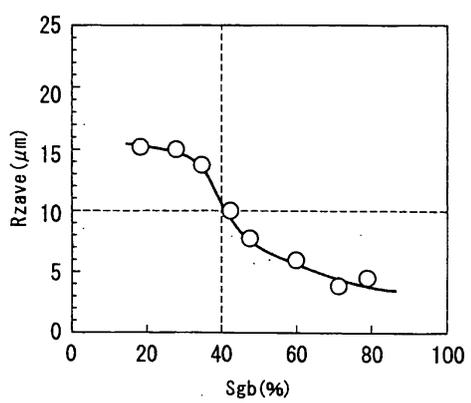
<p>(84) Designated Contracting States: DE FR GB</p> <p>(30) Priority: 31.01.2006 JP 2006023104</p> <p>(71) Applicant: JFE Steel Corporation Tokyo, 100-0011 (JP)</p> <p>(72) Inventors: • SETO, Kazuhiro Tokyo 100-0011 (JP)</p>	<ul style="list-style-type: none"> • YOKOTA, Takeshi Tokyo 100-0011 (JP) • NAKAMURA, Nobuyuki Tokyo 100-0011 (JP) • KARIYA, Nobusuke Tokyo 100-0011 (JP) <p>(74) Representative: Grünecker, Kinkeldey, Stockmair & Schwanhäusser Anwaltssozietät Leopoldstrasse 4 80802 München (DE)</p>
--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

(54) **STEEL SHEET WITH EXCELLENT SUITABILITY FOR FINE BLANKING AND PROCESS FOR PRODUCING THE SAME**

(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 in which a ferrite has an average grain size of from 1 to 10 μm, a cementite has a spheroidization ratio of 80 % or more, and of the cementites, an amount

S_{gb} of a ferrite intergranular cementite which is defined by the following expression (1) : $S_{gb} (\%) = \{S_{on}/(S_{on} + S_{in})\} \times 100$ (wherein S_{on} represents a total occupied area of a cementite present on the ferrite grain boundary of the cementites present per unit area; and S_{in} represents a total occupied area of a cementite present in a ferrite grain of the cementites present per unit area) is 40 % or more. In this way, the steel sheet becomes a steel sheet excellent in FB performance, mold life and performance after FB working.

FIG. 1



EP 1 980 635 A1

Description

TECHNICAL FIELD

5 **[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

10 **[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.

15 **[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.

20 (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.

25 (3) A complicated shape can be blanked by one process. 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.

30 **[0004]** 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.

35 **[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.

40 **[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.

45 **[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.

55 **[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 fine 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 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 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) (spherical cementite) structure in which a cementite amount in ferrite grain is controlled such that an average ferrite grain size is not more than 10 μm , a spheroidization ratio of a cementite is 80 % or more and a ratio of an area of a cementite present on a ferrite grain boundary to an area of the whole of cementites is 40 % or more, the FB performance and the mold life are remarkably improved. Also, it has been newly found that when the cementite amount in ferrite grain is controlled, the fabrication property after the FB working is remarkably improved.

[0018] In the FB working, the material is worked in a state of zero clearance and compression stress. For that reason,

after receiving large deformation, a crack is generated in the material. When a number of cracks are generated during large deformation, the FB performance is largely reduced. In order to prevent the generation of a crack, it is said that spheroidization of a cementite or miniaturization of a cementite particle size is important. However, in the FB working, in the case where even a 100 % spheroidized fine cementite is present in the ferrite grain, the generation of a fine crack is unavoidable. For that reason, the present inventors thought that in the case where stretch flanging working is further applied after the FB working, fine cracks generated at the time of the FB working are connected to each other, leading to a reduction in the stretch flanging property. Also, with respect to the mold life, the present inventors assumed that when a number of cementites are present in the ferrite grain, wear of a cutting blade is accelerated, leading to a reduction in the mold life.

[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 1,150°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 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 (at 720°C for from 5 to 40 hours) as hot rolled sheet annealing. With respect to the steel sheet to which the hot rolled sheet annealing had been thus applied, not only its metallurgical structure was observed, but also its FB performance was evaluated.

[0021] 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), thereby measuring a ferrite grain size and a spheroidization ratio of a cementite.

[0022] 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 number of measured ferrite grains was 5,000 for each.

[0023] Also, a maximum length a and a minimum length b of each cementite were determined in each field of the structure observation (magnification: 3,000 times) by using an image analyzer; its ratio a/b was computed; and the number of cementite grains with a/b of not more than 3 was expressed by a proportion (%) against the total number of measured cementites, thereby defining it as a spheroidization ratio (%) of cementite. Incidentally, the number of measured cementites was 9,000 for each.

[0024] Also, in each field of the structure observation, a cementite present on the ferrite grain boundary and a cementite present in the ferrite grain were discriminated from each other; with respect to the cementites present per unit area, an occupied area S_{on} of a cementite present on the ferrite grain boundary and an occupied area S_{in} of a cementite present in the ferrite grain were measured by using an image analyzer; and an amount (S_{gb}) of a ferrite intergranular cementite as defined by the following expression:

$$S_{gb} (\%) = \{ S_{on} / (S_{on} + S_{in}) \} \times 100$$

was computed. Incidentally, the area of the cementite particle was measured in 30 fields (magnification: 3,000 times) for each.

[0025] Also, a specimen (size: 100 × 80 mm) was collected from the obtained steel sheet and subjected to a fine blanking test (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 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 R_z) 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. 4, 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 μ m in the sheet thickness direction (t direction) by using a contact probe profilometer, and a surface roughness R_z in each scanning line was measured according to JIS B 0601-1994. Furthermore, with respect to the surface roughness R_z on the measured surface, R_z s 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 is defined as "excellent in FB performance". Incidentally, in the case of measuring a surface roughness of a specimen having a sheet thickness different from the foregoing, the measurement may be carried out by repeatedly performing scanning in a pitch of 100 μm in a sheet thickness direction in a region within a range of approximately { (sheet thickness (mm)) - 0.1 mm} in the sheet thickness direction of 0.5 mm from the surface and 10 mm in parallel to the surface to determine Rz on each surface, thereby determining Rz_{ave} from Rz s of the respective surfaces.

[0028] The obtained results are shown in Figs. 1 and 2.

[0029] From a relationship between an average surface roughness Rz_{ave} and a spheroidization ratio of a cementite as shown in Fig. 2, it is noted that when the spheroidization ratio is 80 % or more, Rz_{ave} is not more than 10 μm , and the FB performance is abruptly improved. Incidentally, the data shown in Fig. 2 is concerned with the case where the average ferrite grain size is from approximately 3 to 8 μm . Furthermore, it was acknowledged that when the spheroidization ratio is 80 % or more and the amount of an intergranular cementite increases, Rz_{ave} becomes smaller and the FB performance is remarkably improved. From a relationship between the surface roughness (average surface roughness: Rz_{ave}) and the amount (S_{gb}) of a ferrite intergranular cementite as shown in Fig. 1, when a proportion of the intergranular cementite of the cementites increases such that the amount of a ferrite intergranular cementite is 40 % or more, Rz_{ave} is not more than 10 μm and the FB performance is abruptly improved.

[0030] 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 from 1 to 10 μm , the foregoing cementite has a spheroidization ratio of 80 % or more, and of the foregoing cementites, an amount S_{gb} of a ferrite intergranular cementite which is an amount of a cementite present on a crystal grain boundary of ferrite and which is defined by the following expression (1) is 40 % or more:

$$S_{gb} (\%) = \{ S_{on} / (S_{on} + S_{in}) \} \times 100 \dots (1)$$

(wherein S_{on} represents a total occupied area of a cementite present on the ferrite grain boundary of the cementites present per unit area; and S_{in} represents a total occupied area of a cementite present in a ferrite grain of the cementites present per unit area.)

(2) The steel sheet as set forth in (1), which is characterized in that the cementite present on the crystal grain boundary of the foregoing ferrite has an average particle size of not more than 5 μm .

(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 not more than 0.1 % of Al in terms of % by mass.

(4) The steel sheet as set forth in any one of (1) to (3), 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.

(5) 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; and the foregoing hot rolling is a treatment in which 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, 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.

(6) The manufacturing method of a steel sheet as set forth in (5), 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.

(7) The manufacturing method of a steel sheet as set forth in (5) or (6), 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.

(8) The manufacturing method of a steel sheet as set forth in any one of (5) to (7), which is characterized in that the foregoing hot rolled sheet annealing is carried out at an annealing temperature of from 600 to 750°C.

[0031] According to the invention, a steel sheet which is not only excellent in FB performance but also excellent in fabrication property 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

[0032]

Fig. 1 is a graph to show a relationship between an FB performance (surface roughness on a blanked surface) and an amount of a ferrite intergranular cementite.

Fig. 2 is a graph to show a relationship between an FB performance (surface roughness on a blanked surface) and a spheroidization ratio of a cementite.

Fig. 3 is a graph to show a relationship between an FB performance (surface roughness on a blanked surface) and an average ferrite crystal grain size.

Fig. 4 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

[0033] 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 %

[0034] 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 %

[0035] 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 %

[0036] 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 %

[0037] 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 %

[0038] 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 %.

[0039] 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 %

[0040] 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 fixes N and B forms BN, thereby bringing an effect for 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 %.

[0041] 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 %

[0042] 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 %

[0043] 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 %

[0044] 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 Mo is more preferably from 0.1 to 2.0 %.

Ti: from 0.01 to 0.1 %

[0045] 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 %

[0046] 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 %.

[0047] 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.

[0048] Next, the reasons why the structure of the steel sheet of the invention is limited are described.

[0049] 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.

[0050] In the invention, the grain size of ferrite is from 1 to 10 μm in terms of an average crystal grain size. When the average ferrite crystal grain size is less than 1 μm , not only the steel sheet is remarkably hardened, but also the cementite amount in ferrite grain increases, whereby the fabrication property such as hole expansion property after the FB working as well as the FB performance and the mold life are reduced. On the other hand, when the grain size of ferrite exceeds 10 μm , though the steel sheet is softened, thereby improving the mold life, the FB performance is reduced as shown in Fig. 3. For that reason, the average ferrite crystal grain size was limited to the range of from 1 to 10 μm . Incidentally, the average ferrite crystal grain size is preferably from 1 to 5 μm .

[0051] In the steel sheet of the invention, a spheroidization ratio of the cementite is 80 % or more. When the spheroidization ratio is 80 % or more, the steel sheet is softened, thereby improving the mold life, the FB performance is reduced as shown in Fig. 3. For that reason, the spheroidization ratio of the cementite is preferably 80 % or more.

roidization ratio is less than 80 %, not only the steel sheet becomes hard, but also the deformability is small and the FB performance is reduced. As shown in Fig. 2, when the spheroidization ratio is less than 80 %, Rz ave exceeds 10 μm and becomes large, and the FB performance is abruptly reduced. For that reason, in order to ensure a sufficient FB performance, the spheroidization ratio of a cementite was limited to 80 % or more. Incidentally, in order to make the spheroidization ratio large, since long-term annealing is required, the spheroidization ratio is preferably from 80 to 85 %.

[0052] Also, in the steel sheet of the invention, an amount S_{gb} of a ferrite intergranular cementite is 40 % or more. The amount S_{gb} of a ferrite intergranular cementite is a ratio of an occupied area of a cementite present on the ferrite crystal grain boundary to an occupied area of the whole of cementites and is a value as defined by the following expression (1):

$$S_{gb} (\%) = \{S_{on} / (S_{on} + S_{in})\} \times 100 \dots (1)$$

(wherein S_{on} represents a total occupied area of a cementite present on the ferrite crystal grain boundary of the cementites present per unit area; and S_{in} represents a total occupied area of a cementite present in a ferrite grain of the cementites present per unit area.) When the amount S_{gb} of a ferrite intergranular cementite is less than 40 %, the amount of the cementite present in the ferrite grain is large; Rz ave exceeds 10 μm and becomes large as shown in Fig. 1; and the FB performance is abruptly reduced. It is considered that this is caused due to the matter that when even a fine and spheroidized cementite is present in the ferrite grain, fine cracks are generated in the periphery of the cementite at the time of FB working and connected to each other, thereby reducing the FB performance. It is also considered that when fine cracks are generated in the periphery of the cementite at the time of FB working and remain, these cracks are connected to each other in the subsequent fabrication, leading to a reduction of the fabrication property. Also, when the cementite is present in the ferrite grain, the ferrite grain itself becomes hard, thereby reducing the mold life. For that reason, in the invention, the amount S_{gb} of a ferrite intergranular cementite was limited to 40 % or more. Incidentally, the amount S_{gb} of a ferrite intergranular cementite is preferably 50 % or more.

[0053] Also, in the steel sheet of the invention, it is preferable that the cementite present on the crystal grain boundary of ferrite has an average grain size of not more than 5 μm . This is because it has been newly found that in the case where the amount S_{gb} of a ferrite intergranular cementite is 40 % or more, with respect to the cementite present on the ferrite grain boundary, the smaller the particle size, the more improved the FB working and the larger the contribution to an improvement in mold life. Also, when the particle size of the cementite, in short-time heating in high-frequency quenching, it is possible to easily dissolve the cementite in the austenite, whereby it is easy to ensure a desired quenching hardness. For these reasons, it is preferable that the average particle size of a cementite present on the ferrite crystal grain boundary is limited to not more than 5 μm .

[0054] Next, a preferred manufacturing method of the steel sheet of the invention is described.

[0055] 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.

[0056] Subsequently, the obtained raw steel material is subjected to hot rolling to form a hot rolled sheet by heating and rolling.

[0057] The hot rolling is preferably a treatment in which 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, 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. The hot rolling in the invention is characterized by adjusting the termination temperature of finish rolling and the subsequent cooling condition. Thus, a hot rolled steel sheet having a substantially 100 % pearlite structure is obtained.

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

[0058] It is preferable that the termination temperature of finish rolling is a temperature in the range of from 800 to 950°C, which is a termination temperature region of usual finish rolling. 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. 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.

EP 1 980 635 A1

Average cooling rate after completion of finish rolling: 50°C/s or more

5 **[0059]** 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), whatever the subsequent hot rolled sheet annealing is devised, the amount of the cementite present in the grain increases, and the amount of the cementite present on the grain boundary decreases. Thus, the FB performance is reduced. For these reasons, it is preferable that the average cooling rate after completion of finish rolling is limited to 50°C/s or more. Incidentally, for the purpose of preventing the formation of bentonite, it is more preferable that the average cooling rate after completion of finish rolling is not more than 120°C/s.

15 Cooling stopping temperature: from 500 to 700°C

20 **[0060]** 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 bentonite 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 standing for 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 from 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.

25 **[0061]** After stopping the cooling, the hot rolled sheet is immediately coiled in a coil state. The coiling temperature is preferably from 450 to 600°C, and more preferably from 500 to 600°C.

30 **[0062]** 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.

35 **[0063]** 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. By applying proper hot rolled sheet annealing to the hot rolled sheet having a substantially 100 % pearlite structure, not only the spheroidization of a cementite is accelerated, but also the grain growth of ferrite is inhibited, whereby a large amount of the cementite can be made present on the ferrite crystal grain boundary.

40 **[0064]** Incidentally, in the hot rolled sheet annealing, the annealing temperature is a temperature in the range of from 600 to 750°C. When the annealing temperature is lower than 600°C, spheroidization of the cementite cannot be sufficiently achieved. On the other hand, where the annealing temperature exceeds 750°C and becomes high, pearlite is regenerated during cooling, and the fine blanking performance and other fabrication property are reduced. Incidentally, though a holding time of the hot rolled sheet annealing is not required to be particularly limited, in order to sufficiently spheroidize the cementite, 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, the holding time is preferably not more than 80 hours.

EXAMPLES

45 **[0065]** A raw steel material (slab) having a composition as shown in Table 1 was subjected to hot rolling and hot rolled sheet annealing as shown in Table 2, thereby forming a hot rolled steel sheet (thickness: 4.3 mm).

50 **[0066]** The obtained hot rolled steel sheet was examined with respect to the structure, FB performance and stretch flanging property after the FB performance. The examination methods are as follows.

(1) Structure:

55 **[0067]** 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); and a volume ratio of ferrite and a cementite, a ferrite grain size, a spheroidization ratio of a cementite, an amount of ferrite intergranular cementite and an average particle size of a cementite on the ferrite grain boundary were measured.

[0068] 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 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.

[0069] 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.

[0070] With respect to the spheroidization ratio of a cementite, a maximum length a and a minimum length b of each cementite were determined in each field (field number: 30 pieces) of the structure observation (magnification: 3,000 times) by using an image analyzer; its ratio a/b was computed; and the number of cementite grains of a/b with not more than 3 was expressed by a proportion (%) against the total number of measured cementites, thereby defining it as a spheroidization ratio (%) of cementite.

[0071] With respect to the amount (S_{gb}) of a ferrite intergranular cementite, in each field (field number: 30 pieces) of the structure observation (magnification: 3,000 times), a cementite present on the ferrite grain boundary and a cementite present in the ferrite grain were discriminated from each other; an occupied area S_{on} of a cementite present on the ferrite grain boundary and occupied area S_{in} of a cementite present in the ferrite grain were measured by using an image analyzer; and an amount (S_{gb}) of a ferrite intergranular cementite was computed according to the following expression (1).

$$S_{gb} (\%) = \{ S_{on} / (S_{on} + S_{in}) \} \times 100 \dots (1)$$

[0072] Also, with respect to each cementite present on the ferrite grain boundary, 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 averaged, and its value was defined as a cementite average particle size in ferrite grain.

(2) FB performance:

[0073] 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 $60 \text{ mm} \times 40 \text{ mm}$ (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 R_z) 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.

[0074] That is, with respect to the measurement of the surface roughness, as illustrated in Fig. 4, 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 R_z in each scanning line was measured according to JIS B 0601-1994. Furthermore, with respect to the surface roughness R_z on the measured surface, R_z s 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 $R_z \text{ ave}$ (μm) defined according to the following expression was computed.

$$R_z \text{ ave} = (R_z 1 + R_z 2 + R_z 3 + R_z 4) / 4$$

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

[0075] Also, the life of the used tool (mold) was evaluated. A surface roughness (ten-point average roughness R_z) 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 $R_z \text{ ave}$ of the sample end surface is not more than 10 μm is defined as "O"; 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) Stretch flanging property after FB working:

5 **[0076]** A specimen (size: 100 mm × 100 mm) was blanked from the obtained steel sheet by FB working, thereby examining a stretch flanging property. Incidentally, 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.

10 **[0077]** The stretch flanging property was evaluated by carrying out a hole expansion test to determine a hole expansion ratio λ. The hole expansion test was carried out by a method in which a punch hole of 10 mmφ (d₀) was blanked in a specimen and expanding the subject hole by a tool; a hole size d at the point of time when a through thickness crack was generated in a flange of the punch hole was determined; and a hole expansion ratio λ (%) as defined by the following expression was determined.

15
$$\lambda (\%) = (d - d_0) / d_0 \times 100$$

[0078] The obtained results are shown in Table 2, too.

20 **[0079]** 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 stretch flanging property after FB working. Incidentally, the volume ratio of ferrite and a cementite was confirmed in the foregoing method. As a result, in all of the examples of the invention, it was confirmed that the sum of

25 volume ratio of the ferrite and cementite is 95 % or more, thereby forming a structure composed mainly of ferrite and a cementite. Also, the particle size of a cementite present on the ferrite crystal grain boundary was confirmed by the foregoing method. As a result, in all of the examples of the invention, the average particle size was not more than 5 μm.

30 **[0080]** On the other hand, in the examples of comparison falling outside the scope of the invention, the surface roughness Rz on the blanked surface exceeds 10 μm and becomes coarse, whereby a reduction of the FB performance is confirmed, the mold life is reduced, and the stretch flanging property is reduced. Incidentally, in the steel sheet No. 15, since a crack was generated at the time of coiling, the hot rolled sheet annealing and subsequent treatments were not carried out.

35

40

45

50

55

5

10

15

20

25

30

35

40

45

50

55

Table 1

Steel No.	Chemical components (% by mass)											Remark	
	C	Si	Mn	P	S	Al	N	Cr	Mo	Ni	Ti		B
A	0.20	0.18	0.83	0.011	0.006	0.044	0.0035	-	-	-	-	-	Invention
B	0.35	0.18	0.79	0.014	0.006	0.028	0.0038	-	-	-	-	-	Invention
C	0.44	0.22	0.76	0.012	0.007	0.021	0.0042	-	-	-	-	-	Invention
D	0.20	0.17	0.74	0.017	0.009	0.025	0.0028	1.21	-	-	-	-	Invention
E	0.16	0.17	0.88	0.012	0.008	0.024	0.0034	-	0.27	-	-	-	Invention
F	0.21	0.21	0.73	0.014	0.005	0.022	0.0031	-	-	1.48	-	-	Invention
G	0.19	0.16	0.74	0.015	0.007	0.023	0.0029	-	-	-	0.04	-	Invention
H	0.21	0.18	0.73	0.014	0.007	0.029	0.0044	-	-	-	-	0.0024	Invention
I	0.23	0.22	0.81	0.012	0.006	0.035	0.0035	-	-	-	0.02	0.0016	Invention
J	0.22	0.23	0.69	0.017	0.006	0.026	0.0037	0.79	0.41	0.72	-	-	Invention
K	0.21	0.24	0.71	0.015	0.006	0.025	0.0042	0.78	0.28	1.23	0.02	0.0019	Invention
L	0.34	0.65	0.83	0.015	0.006	0.017	0.0044	-	-	-	-	-	Comparison
M	0.36	0.23	1.67	0.014	0.008	0.022	0.0033	-	-	-	-	-	Comparison
N	0.36	0.18	0.72	0.011	0.006	-	0.0042	-	-	-	-	-	Invention
O	0.35	0.05	0.75	0.013	0.007	0.031	0.0040	-	-	-	-	-	Invention
P	0.22	0.20	0.70	0.013	0.006	-	0.0038	0.80	0.25	1.05	-	-	Invention

Table 2

Steel sheet No.	Hot rolling condition				Hot rolled sheet annealing condition		Sheet thickness (mm)	Structure			FB performance		Performance after FB working	Remark	
	Termination temperature of finish rolling (°C)	Cooling rate (°C/s)	Cooling stopping temperature (°C)	Coiling temperature (°C)	Annealing temperature (°C)	Holding time (hr)		Average ferrite grain size (μm)	Spheroidization ratio (%)	S _{ph} (%)	Surface roughness Rz ave on blanked surface (μm)	Mold life			Hole expansion ratio λ (%)
1	A	865	70	620	570	710	30	4.3	9.5	86	65	8	○	105	Invention
2	B	860	100	630	550	720	40	4.3	9.2	92	68	8	○	93	Invention
3	B	865	30	620	510	720	50	4.3	12.7	81	38	15	△	54	Comparison
4	B	860	100	730	590	720	40	4.3	15.1	74	35	17	×	47	Comparison
5	B	865	100	400	350	710	50	4.3	-	-	-	-	-	-	Comparison
6	C	840	80	620	580	710	40	4.3	8.8	90	67	8	○	80	Invention
7	D	855	80	650	550	720	30	4.3	8.6	92	48	9	○	121	Invention
8	E	860	100	620	520	700	30	4.3	7.9	85	56	6	○	125	Invention
9	F	855	90	600	480	730	40	4.3	9.8	87	66	7	○	113	Invention
10	G	860	80	630	550	710	50	4.3	5.7	83	63	6	○	108	Invention
11	H	860	80	640	570	720	30	4.3	9.4	84	64	7	○	94	Invention
12	I	865	80	650	540	720	40	4.3	8.5	86	70	9	○	96	Invention
13	J	870	100	590	500	720	40	4.3	6.9	93	68	8	○	105	Invention
14	K	860	120	630	570	730	60	4.3	5.2	90	62	8	○	90	Invention
15	L	860	100	640	530	690	30	4.3	8.2	82	54	14	△	49	Comparison
16	M	865	100	630	560	720	30	4.3	6.0	84	53	13	△	55	Comparison
17	N	860	90	610	510	720	40	4.3	7.4	92	58	9	○	75	Invention
18	O	855	80	600	540	710	30	4.3	8.3	85	52	9	○	89	Invention
19	P	865	80	580	490	710	40	4.3	7.1	88	45	8	○	92	Invention

Claims

- 5 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 from 1 to 10 μm , said cementite has a spheroidization ratio of 80 % or more, and of said cementites, an amount S_{gb} of a ferrite intergranular cementite which is an amount of a cementite present on a crystal grain boundary of ferrite and which is defined by the following expression (1) is 40 % or more:

$$S_{\text{gb}} (\%) = \{S_{\text{on}} / (S_{\text{on}} + S_{\text{in}})\} \times 100 \dots (1)$$

15 wherein S_{on} represents a total occupied area of a cementite present on the ferrite grain boundary of the cementites present per unit area; and S_{in} represents a total occupied area of a cementite present in a ferrite grain of the cementites present per unit area.

- 20 2. The steel sheet according to claim 1, which is **characterized in that** the cementite present on the crystal grain boundary of said ferrite has an average particle size of not more than 5 μm .
3. The steel sheet according to claim 1 or 2, 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.
- 25 4. The steel sheet according to any one of claims 1 to 3, 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.
- 30 5. 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** 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; and said hot rolling is a treatment in which 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, 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.
- 40 6. The manufacturing method of a steel sheet according to claim 5, 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.
7. The manufacturing method of a steel sheet according to claim 5 or 6, 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.
- 45 8. The manufacturing method of a steel sheet according to any one of claims 5 to 7, which is **characterized in that** said hot rolled sheet annealing is carried out at an annealing temperature of from 600 to 750°C.

FIG. 1

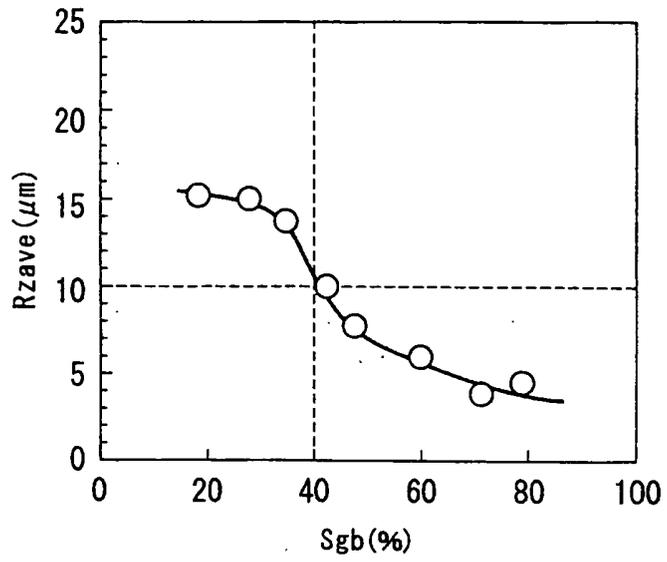


FIG. 2

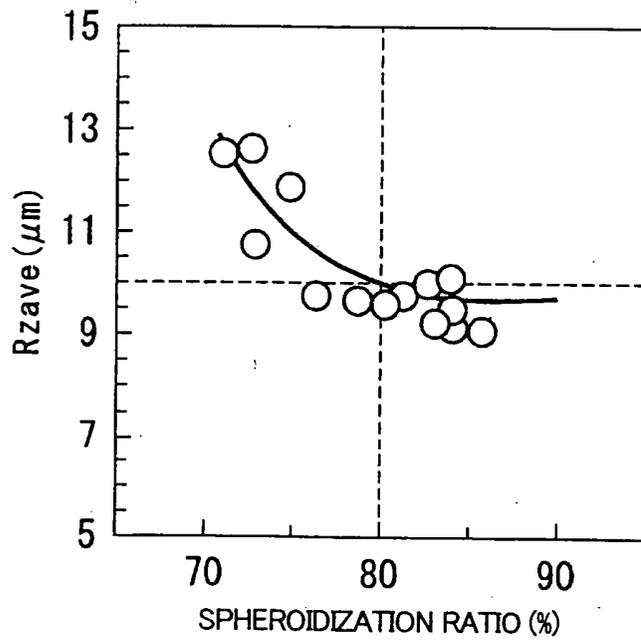


FIG. 3

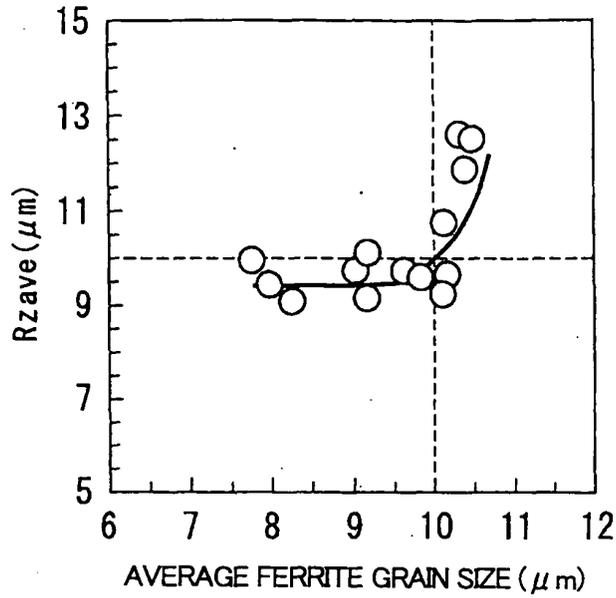
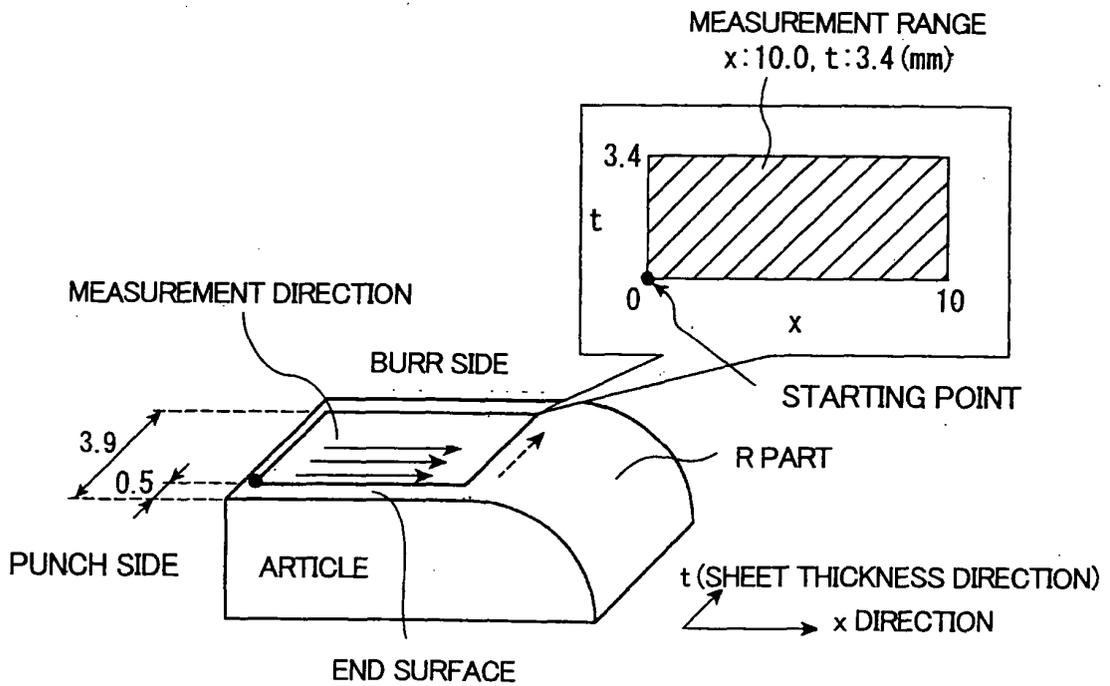


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/051835

<p>A. CLASSIFICATION OF SUBJECT MATTER <i>C22C38/00(2006.01) i, C21D9/46(2006.01) i</i></p> <p>According to International Patent Classification (IPC) or to both national classification and IPC</p>														
<p>B. FIELDS SEARCHED</p> <p>Minimum documentation searched (classification system followed by classification symbols) <i>C22C38/00, C21D9/46</i></p> <p>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched <i>Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2007</i> <i>Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007</i></p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)</p>														
<p>C. DOCUMENTS CONSIDERED TO BE RELEVANT</p> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>E, X</td> <td>JP 2007-31762 A (JFE Steel Corp.), 08 February, 2007 (08.02.07), Claims; Par. No. [0031] (Family: none)</td> <td>4, 7, 8</td> </tr> <tr> <td>A</td> <td>JP 2000-265240 A (Nisshin Steel Co., Ltd.), 26 September, 2000 (26.09.00), Claims (Family: none)</td> <td>1-8</td> </tr> <tr> <td>A</td> <td>JP 2001-140037 A (Nippon Steel Corp.), 22 May, 2001 (22.05.01), Claims (Family: none)</td> <td>1-8</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	E, X	JP 2007-31762 A (JFE Steel Corp.), 08 February, 2007 (08.02.07), Claims; Par. No. [0031] (Family: none)	4, 7, 8	A	JP 2000-265240 A (Nisshin Steel Co., Ltd.), 26 September, 2000 (26.09.00), Claims (Family: none)	1-8	A	JP 2001-140037 A (Nippon Steel Corp.), 22 May, 2001 (22.05.01), Claims (Family: none)	1-8
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.												
E, X	JP 2007-31762 A (JFE Steel Corp.), 08 February, 2007 (08.02.07), Claims; Par. No. [0031] (Family: none)	4, 7, 8												
A	JP 2000-265240 A (Nisshin Steel Co., Ltd.), 26 September, 2000 (26.09.00), Claims (Family: none)	1-8												
A	JP 2001-140037 A (Nippon Steel Corp.), 22 May, 2001 (22.05.01), Claims (Family: none)	1-8												
<p><input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.</p>														
<p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"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</p> <p>"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</p> <p>"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</p> <p>"&" document member of the same patent family</p>														
<p>Date of the actual completion of the international search 13 March, 2007 (13.03.07)</p>		<p>Date of mailing of the international search report 20 March, 2007 (20.03.07)</p>												
<p>Name and mailing address of the ISA/ Japanese Patent Office</p>		<p>Authorized officer</p>												
<p>Facsimile No.</p>		<p>Telephone No.</p>												

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/051835

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 2002-155339 A (Nisshin Steel Co., Ltd.), 31 May, 2002 (31.05.02), Claims (Family: none)	1-8
A	JP 55-85626 A (Nisshin Steel Co., Ltd.), 27 June, 1980 (27.06.80), Claims (Family: none)	1-8
A	JP 8-295927 A (Nisshin Steel Co., Ltd.), 12 November, 1996 (12.11.96), Claims (Family: none)	1-8
A	JP 55-50427 A (Kawasaki Steel Corp.), 12 April, 1980 (12.04.80), Claims (Family: none)	1-8

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

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]