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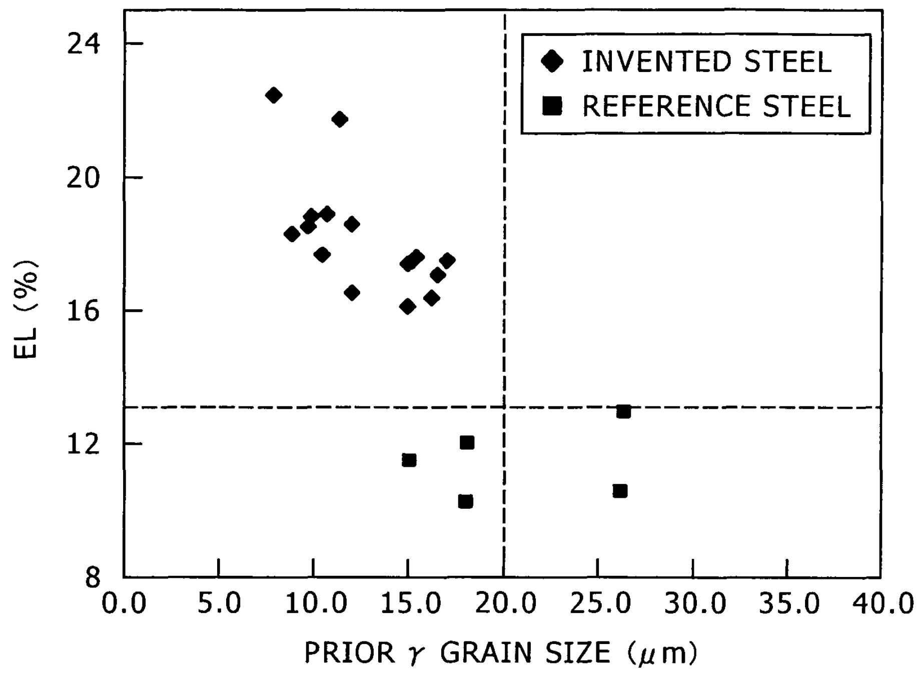
(54) **High strength plate with 980 MPa or above tensile strength excellent in bending workability**

(57) The high strength steel plate contains C: 0.1-0.25% (means mass%, hereinafter the same with respect to the chemical componential composition), Si: 0.1-0.5%, Mn: 0.5-2.0%, Cr: 0.1-1.5%, Mo: 0.1-0.5%, Ti: 0.01-0.05%, and Nb: 0.01-0.05% respectively, and contains V: 0.01-0.05% and/or B: 0.0001-0.005%, and the balance comprises iron with inevitable impurities, wherein the average grain size of prior austenite is 20 μm or below, the standard deviation (σ) of prior austenite grain size distribution is 5 μm or below, and the tensile strength is 980 MPa or above. With such constitution, high strength can be maintained while bending workability becomes excellent as well.

FIG. 1



EP 2 105 515 A2

Description

[0001] The present invention relates to a high strength steel plate excellent in bending workability while maintaining high strength with 980 MPa or above tensile strength, particularly to a steel plate which can be used suitably for construction machine structure that is desired to be large in size.

[0002] In recent years, urbanization has been progressing rapidly in the countries including China in the center. Accordingly, construction quantity related with civil and building works has been increasing, and the demand for construction machines has a tendency to increase intensively.

[0003] On the other hand, improvement of the work efficiency by the construction machine structure is expected to become important in urban development from now on, and enlargement of the size of the construction machine structure to improve work efficiency is also on progress. However, to cope with the earth environmental problems, the weight limit of the crane itself is becoming severe, and a thick steel plate with higher strength (980 MPa or above of tensile strength, for example) is required.

[0004] Also, when such high strength thick steel plate is to be applied to the construction machine structure, excellent workability (particularly bending workability) is required. However, high strength and workability are mutually contradictory characteristics, and it is difficult to satisfy the both characteristics.

[0005] As the technology for improving uniform elongation for the high-tensile thick steel plate with 780 MPa or above tensile strength, a technology shown in the Japanese Unexamined Patent Publication No. 2002-88440, for example, is proposed. According to the technology, uniform elongation is improved by increasing hindrance of dislocation by refinement (7 or above of the grain number or 10 μm or below of the average of the thickness in the plate thickness direction) of prior austenite (may be abbreviated hereinafter as "prior γ") grain size and enhancement of work hardening capability. However, it was found that workability does not necessarily become excellent only by refinement of the prior γ grain size.

[0006] The present invention was developed under such circumstance and its purpose was to provide a high strength steel plate excellent in bending workability while maintaining high strength with 980 MPa or above tensile strength.

[0007] The high strength steel plate according to a primary aspect of the present invention that could achieve the purpose described above contains C: 0.1-0.25% (means mass%, hereinafter the same with respect to the chemical componential composition), Si: 0.1-0.5%, Mn: 0.5-2.0%, Cr: 0.1-1.5%, Mo: 0.1-0.5%, Ti: 0.01-0.05%, and Nb: 0.01-0.05% respectively, contains at least either one of V: 0.01-0.05% and B: 0.0001-0.005%, and the balance comprising iron with inevitable impurities, wherein the average grain size of prior austenite is 20 μm or below, the standard deviation (σ) of prior austenite grain size distribution is 5 μm or below, and the tensile strength is 980 MPa or above.

[0008] In the high strength steel plate according to this aspect, it is effective to further contain Ca: 0.0005-0.01% according to need, thereby the characteristic of the high strength steel plate can be further improved.

[0009] According to the aspect of the present invention, the high strength steel plate excellent in bending workability while maintaining high strength with as high as 980 MPa or above tensile strength can be realized by appropriately adjusting the chemical componential composition and controlling the average grain size of prior γ and the standard deviation (σ) of the prior γ grain size distribution to an appropriate range, and such steel plate is extremely useful as the material for large sized construction machine structure.

[0010]

FIG. 1 is graph showing the relation between the prior γ grain size (average value) and the total elongation EL.

FIG. 2 is a graph showing the relation between the standard deviation (σ) and the total elongation EL.

[0011] The present inventor made investigations from various angles to realize excellent bending workability in the steel plate with 980 MPa or above of the tensile strength. With respect to structure, it is proposed to refine the prior γ grain size for improving uniform elongation (the Japanese Unexamined Patent Publication No. 2002-88440). However it was revealed that bending workability was not necessarily improved by only refinement of the prior γ grain size. Therefore, the present inventor made investigations on the cause of occurrence of such phenomenon.

[0012] As a result, it became clear that, in such a steel plate as described above, anisotropy of the prior γ grain size was not taken into consideration at all, anisotropy became extreme according to some chemical componential composition and manufacturing condition which became the cause of occurrence of variation in the steel plate material, and such variation further caused variation in strength and toughness as well as in the uniform elongation, thereby workability was deteriorated.

[0013] Therefore, with the conception that not only refinement of the prior γ grain size but also lowering of its variation would improve elongation and thereby improve bending workability as well, the present inventor proceeded with the investigations of its concrete embodiments with respect to the chemical componential composition and manufacturing condition. In particular, with the conception that occurrence of uneven recrystallized grain growth by a variety of factors would cause the occurrence of variation, the condition for inhibiting such uneven recrystallized grain growth was investigated.

[0014] As a result, with respect to the direction of setting the chemical componential composition, following knowledge was obtained. In order to realize the steel plate with 980 MPa or above of the tensile strength, it was conventionally regarded that addition of Cu and Ni and the like which were high in solid solution enhancement capacity was useful, however, the component base that did not contain such elements at all was adopted for the steel plate in accordance with the present invention. Consequently, recrystallization temperature range becomes wider compared with that of the conventional component base one, encroachment into the unevenly generated recrystallized structure occurs more frequently, and more even structure can be obtained easily. Also, by adding appropriate quantity of Nb and Ti, the pinning effect of the crystal grains by carbonitride of them is exerted, and refinement of the prior γ grain size becomes possible.

[0015] On the other hand, the present inventor could obtain following knowledge on the manufacturing condition for inhibiting generation of uneven recrystallized structure. First, the longest interpass time during finish rolling is set to 15 s or shorter, and the rolling is controlled to even rolling reduction with the draft per one pass during rolling of one steel plate being made approximately 20-30% for at least 3 times, thereby recrystallization occurring unevenly is inhibited, and further, by increase of the nucleus generation sites, even and fine structure can be obtained. In this connection, the interpass time means the time from when the leading edge of the steel plate in the longitudinal direction is rolled down until when the same position in the next pass is rolled down in the next pass.

[0016] In this regard, it was considered that refinement and uniformization of the prior γ grain size were achieved by controlling frequency of recrystallization and growth of the recrystallized grain before rolling by stipulating the interpass time and controlling the strain quantity occurring in rolling and controlling frequency of generation of recrystallized grain by stipulating the draft per one pass.

[0017] In accordance with the present invention, by adopting the measures described above, the prior γ grain size can be refined, its variation can be lowered, and bending workability is improved. As the criterion of refinement of the prior γ grain size, it is necessary to make the average grain size of the prior γ 20μm or below. By this, elongation required for improvement of workability becomes high. However, only achievement of refinement of the prior γ grain size does not achieve the purpose of the present invention, and its variation must be lowered as well. As an indication for it, the standard deviation (σ) of the crystallized grain size distribution should be 5 μm or below. In this regard, the standard deviation σ is obtained by the method described below.

[Measuring Method of Standard Deviation σ]

[0018] Micro.structure is observed by 400 times magnification using an optical microscope, the observation field is evenly divided by five vertically and laterally respectively, the cutting length (xi) respective line segment cuts the crystal grain (the prior γ grain) is measured, its distribution is obtained from the measurement result, the average value and variation are obtained in accordance with the equations (1) and (2) described below, and thereafter the square root of the variation is made the standard deviation.

[0019]

[Equation 1]

$$(\text{Average value}) \qquad \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \cdots (1)$$

[0020]

[Equation 2]

$$(\text{Variation}) \qquad \sigma^2 = \frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 \qquad \cdots (2)$$

[0021] As the factor for improving bending workability, influence of the maximum crystal grain size might be conceivable, however, in the high strength steel plate in accordance with the present invention, the crystal grain (the prior γ grain) showed distribution close to the normal distribution, therefore the maximum crystal grain size was considered to hardly become a problem. The case such maximum crystal grain size becomes a problem is the case of the low alloy steel, and in the case of such high alloy steel of 980 MPa or above strength class as the steel plate in accordance with the present invention, the temperature range wherein abnormal growth of the crystal grain occurs is low and the driving force is small, therefore the abnormal growth of the crystal grain hardly occurs. Accordingly, in the present invention, the characteristics can be evaluated not by the maximum grain size but by simply stipulating the standard deviation.

[0022] When the steel plate excellent in elongation is to be manufactured, the structure with high anisotropy becomes overwhelmingly disadvantageous because it results in causing anisotropy of material. As in the present invention, by making the grain size of the structure even, the steel plate excellent in bending workability can be obtained. Also, by refinement of structure unit, the grain boundary per unit area which becomes hindrance of dislocation increases, resulting in improvement in elongation. In other words, if material is with high work hardening characteristic, even if stress is applied locally in tensioning, because the position exerts very high work hardening capability, deformation in the position does not proceed further but proceeds in other positions not work hardened yet. As a result, in the structure with high work hardening capability (fine structure), elongation becomes large.

[0023] The reason of occurrence of the phenomenon described above by refinement of the structure is based on the pile-up theory of dislocation within a crystal grain, and the grain boundary is known to act as a pile-up site of dislocation. Among the grain boundaries, there are a prior γ grain boundary, bucket grain boundary, block grain boundary, lath grain boundary, and the like, the prior γ grain boundary having the largest orientation difference in neighboring crystal grains is known to have high function as the pile-up site of dislocation, and as the dominant factor governing the elongation, the prior γ grain size is considered to be most influential.

[0024] Further, the steel plate in accordance with the present invention is eventually made the tempered martensite structure and the tempered bainite structure and is made the steel plate with 980 MPa or above tensile strength by a manufacturing method described below, however, in any structure, the prior γ grain size is kept in the final product, and the effect described above can be achieved by refinement of the prior γ grain size.

[0025] In the high strength steel plate in accordance with the present invention, from the viewpoint of refinement of the structure, the content of Ti and Nb should be adjusted appropriately, and in addition, other fundamental components such as C, Si, Mn, Cr, Mo should be controlled appropriately as well. The reasons of limiting the range for these elements are as described below.

[0026] [C: 0.1-0.25%]

C is an element indispensable for improving the strength, and in the manufacturing method by reheating and quenching / tempering (QT method described below), in order to obtain high strength of 980 MPa or above tensile strength with C content of below 0.1%, other alloy elements should be added much, which results in cost increase. Preferable content is 0.20% or above. However, if C content is excessive, toughness and weldability are extremely deteriorated, therefore it should be made 0.25% or below.

[0027] [Si: 0.1-0.5%]

Although Si is an element indispensable for high strengthening and deoxidization of steel, if it is below 0.1%, such effect cannot be exerted enough, and toughness lowers if it is contained excessively exceeding 0.5%. Therefore, Si content should be 0.1-0.5%. Preferable lower limit is 0.15% and preferable upper limit is 0.35%.

[0028] [Mn: 0.5-2.0%] Mn is effective as an element for enhancing quenchability of a steel plate and improving the strength and toughness. In order to exert such effects, Mn content should be 0.5% or above, preferably 0.80% or above. However, if Mn is contained excessively, toughness of welding section is degraded, therefore the upper limit is made 2.0%.

[0029] [Cr: 0.1-1.5%] Similarly to Mn, Cr is effective as an element for enhancing quenchability with the little addition. In order to exert such effect, Cr content should be 0.1% or above, preferably 0.30% or above. However, if Cr is contained excessively, toughness of welding section is degraded, therefore the upper limit is made 1.5%, preferably 1.0%.

[0030] [Mo: 0.1-0.5%] Mo has the effect of securing strength after annealing. In order to exert such effect, Mo should be contained 0.1% or above. However, even if Mo is excessively contained more than 0.5%, not only the effect is saturated but toughness of the steel plate is lowered on the contrary. Therefore, Mo content was stipulated as 0.1-0.5%. Preferable upper limit is 0.20%.

[0031] [Ti: 0.01-0.05%] Ti is easy in forming fine carbonitride, and has the effects of forming fine prior γ grains by pinning the crystal grain boundaries and dislocations with the little addition and contributing to strengthening of steel plates. In order to exert such effects, its content should be 0.01% or above, however, if Ti content is excessive and exceeds 0.05%, it becomes the cause of deterioration of toughness. Preferable upper limit is 0.03%.

[0032] [Nb: 0.01-0.05%] Similarly to Ti, Nb is easy in forming fine carbonitride, and has the effects of forming fine prior γ grains by pinning the crystal grain boundaries and dislocations and contributing to strengthening of steel plates. In order to exert such effects, its content should be 0.01% or above, however, if Nb content is excessive and exceeds 0.05%, it becomes the cause of deterioration of toughness. Preferable upper limit is 0.03%.

[0033] [V: 0.01-0.05% and/or B: 0.0001-0.005%] Both of V and B are elements effective in strengthening steel. Out of them, similarly to Ti and Nb, V is easy in forming fine carbonitride, and has the effects of forming fine prior γ grains by pinning the crystal grain boundaries and dislocations and contributing to strengthening of steel plates. In order to exert such effects, V content should be 0.01% or above, however, if its content is excessive and exceeds 0.05%, it becomes the cause of deterioration of toughness. Preferable upper limit is 0.02%.

[0034] On the other hand, B exerts the effects of improving quenchability of steel and enhancing strength of steel plates by solid solution strengthening with the extremely little addition. In order to exert such effects, B content should be 0.0001% or above, preferably 0.0005% or above. However, if its content is excessive and exceeds 0.005%, it becomes the cause of deterioration of toughness. Preferable upper limit is 0.002%.

[0035] In the high strength steel plate in accordance with the present invention, the components other than those described above are iron and inevitable impurities, however, trace amount components (allowable components) mixed in inevitably in smelting can be also contained (P, S, O and the like, for example), and such steel plates are to be also included in the range of the present invention. Also, in the high strength steel plate in accordance with the present invention, it is also effective to further contain Ca: 0.0005-0.01% if necessary, and the characteristic of the high strength steel plate can be further improved by inclusion of Ca. The reasons of limiting the range in containing Ca are as described below.

[0036] [Ca: 0.0005-0.01%] Ca is effective in enhancing toughness by controlling non-metallic inclusions. In order to exert such effect, it is preferable to contain Ca by 0.0005% or above, more preferably 0.0010% or above. However, even if Ca content exceeds 0.01% and becomes excessive, its effect saturates, therefore it is preferable to make it 0.01% or below. More preferable upper limit is 0.0025%.

[0037] In order to manufacture the high strength steel plate in accordance with the present invention, from the viewpoint of inhibiting generation of uneven recrystallized structure, it is necessary to make the longest interpass time during finish rolling 15 s or shorter and to perform even rolling reduction with the draft of approximately 20-30% per one pass for at least 3 passes in finish rolling of one steel plate, but with respect to other conditions, ordinary manufacturing conditions can be followed. However, in the method wherein quenching and tempering are performed directly from hot rolling after continuous casting (hereinafter referred to as "DQ-T method"), the prior γ grain size does not become large, but variation of the structure attributed to uneven cooling in accelerated cooling process is liable to occur, therefore variation of the prior γ grain size is liable to become large, which is not desirable.

[0038] From such viewpoint, the method is preferable wherein after the continuous casting, hot rolling is performed, thereafter, after cooling, quenching and tempering are carried out. More specifically, the steel of such chemical component base as described above is smelted by a converter and the cast slab obtained is hot rolled at approximately 1,100-700 DEG C. The rolling condition then is; after rolling to 120 mm or below of the plate thickness by a roughing mill, rolling is performed under the conditions described above (interpass time, draft per one pass) by a finishing mill, and the rolling is finished with the rolling finishing temperature at the recrystallizing temperature or above. The plate thickness then is 6-50 mm.

[0039] After the rolling described above, cooling is performed down to 100 DEG C. or below in the open air, thereafter reheating and quenching process is performed. The quenching condition then is; heating to the heating temperature: 880-930 DEG C., maintaining for 5-15 min at the temperature, thereafter water-quenching. Further, after the quenching process, the temperature of the steel plate is made 100 DEG C, or below, thereafter the tempering process is performed. The tempering condition then is; heating to the temperature: 300-500 DEG C., maintaining for 5-15 min at the temperature, thereafter air-cooling in the open air (this method is hereinafter referred to as "QT method").

[0040] Although the present invention is described below in further detail by referring to the examples, the present invention is by no means limited by the examples below and can of course be implemented with modifications added within the scope adaptable to the purposes described above and below, and any of them is to be included within the technical range of the present invention.

EXAMPLE

[Example 1]

[0041] The steel of the chemical componential composition shown in Table 1 below was smelted by an ordinary method, and various kinds of steel plates were manufactured according to the method described above (QT method). The steel plates with quenching and tempering continuously performed after hot rolling without cooling (DQ-T method) were also manufactured (Nos. 16, 17 in Table 2 below).

[0042]

[Table 1]

No.	Chemical componential composition of steel plate * (mass%)									
	C	Si	Mn	Cr	Mo	V	Nb	Ti	B	Ca
1	0.15	0.24	1.15	0.66	0.29	0.041	0.012	0.018	0.0023	-
2	0.13	0.21	1.07	0.68	0.30	0.033	0.014	0.010	0.0015	0.0010
3	0.14	0.24	1.12	0.69	0.28	0.031	0.016	0.049	0.0012	0.0015
4	0.14	0.21	1.20	0.67	0.34	0.040	0.048	0.017	0.0013	0.0010
5	0.13	0.20	1.16	0.60	0.10	0.036	0.020	0.020	0.0013	0.0014
6	0.14	0.27	1.22	0.65	0.50	0.031	0.011	0.018	0.0010	0.0013
7	0.16	0.25	1.09	0.20	0.34	0.036	0.012	0.018	0.0010	0.0015
8	0.12	0.29	1.11	1.19	0.30	0.034	0.012	0.019	0.0015	0.0010
9	0.15	0.24	1.06	0.61	0.31	-	0.017	0.023	0.0011	0.0014
10	0.18	0.22	0.52	0.68	0.29	0.033	0.016	0.015	0.0011	-
11	0.18	0.24	2.00	0.70	0.30	0.039	0.010	0.025	-	0.0011
12	0.16	0.10	1.17	0.65	0.25	0.032	0.017	0.017	0.0013	0.0013
13	0.15	0.50	1.08	0.66	0.26	0.039	0.012	0.020	0.0011	0.0013
14	0.10	0.20	1.06	0.60	0.25	0.037	0.018	0.020	0.0012	0.0013
15	0.25	0.28	1.20	0.65	0.33	0.035	0.013	0.020	0.0013	0.0015
16	0.10	0.48	1.00	0.24	0.21	0.074	-	0.021	0.0012	-
17	0.11	0.25	1.15	0.20	0.10	0.035	0.015	0.020	0.0015	0.0014
18	0.14	0.27	1.15	0.60	0.25	0.032	-	0.020	0.0015	0.0014
19	0.14	0.26	1.10	0.60	0.34	-	0.002	0.001	0.0010	0.0011
20	0.15	0.24	1.03	0.64	0.35	0.041	0.003	-	0.0011	0.0010
21	0.12	0.35	1.36	0.18	0.05	0.025	-	0.015	0.0001	0.0014
*Balance: Iron and inevitable impurities										

[0043] With regard to respective steel plate obtained, the tensile tests were performed and the mechanical properties (tensile strength TS, total elongation EL of the steel plate) were measured in accordance with the method described below, the prior γ grain sizes were measured by a method described below, and the grain sizes were quantitatively evaluated statistically.

[Measuring Method of Mechanical Properties]

[0044] As the test pieces for the tensile tests, No. 5 test pieces of JIS Z 2201 (for the cases of 4.5 - 6 mm plate thickness), No. 1A test pieces of JIS Z 2201 (for the cases of 6-40 mm plate thickness), or No. 4 test pieces of JIS Z 2201 (for the cases of 40-50 mm plate thickness) were used, and the test pieces were machined so that the direction perpendicular to the rolling direction became the longitudinal direction. The tensile tests were performed in accordance with the manner described in JIS Z 2241 using these test pieces, and the tensile strength TS and total elongation EL of the steel plate were measured. The test piece extracted position was made the position of 1/4 depth of the steel plate in the plate thickness direction. Also, with respect to the tensile strength TS, it was necessary to secure at least 980MPa or above, and, with respect to the total elongation EL, the criterion was set at 13% which was regarded to be required not to cause a bending crack in working of thick plate products.

[Measurement Method of Prior γ Grain Size]

[0045] The cross-sectional sections parallel to the rolling direction of the steel plates were observed by an optical microscope. The observation conditions then were made; magnification of observation: 400 times, observation position was 1/4 position in the plate thickness direction, and the numbers of the observation fields were 10 optional observation fields. The total observation area was 3×10^2 (μm^2) per one sample. In order to facilitate observation of the samples then, the chemical corrosion was practiced by a corrosive liquid containing picric acid, hydrochloric acid, surface active agent, and the like. Then, the average value and the standard deviation σ of the prior γ grain size were obtained in accordance with the method described above.

[0046] The results are shown in Table 2 below along with the manufacturing method (QT method or DQ-T method), the longest interpass time, and the draft (average draft per one time when rolling down was performed almost evenly for 3 times). Also, on the basis of these results, the relation between the prior γ grain size (average value) and the total elongation EL is shown in FIG. 1 and the relation between the standard deviation σ and the total elongation EL is shown in FIG. 2 respectively.

[0047]

[Table 2]

No.	Plate thickness (mm)	Manufacturing method	Longest interpass time (s)	Average draft (%)	Tensile strength TS (MPa)	Elongation EL (%)	Average prior γ grain size (μm)	Standard deviation (σ) of prior γ grain size
1	13	QT	10	25	1108	18.8	10.8	4.7
2	12	QT	8	27	1060	18.2	9.0	5.0
3	12	QT	8	27	1065	22.4	8.1	4.0
4	12	QT	10	25	1071	18.5	9.8	4.2
5	25	QT	14	24	1010	21.7	11.3	3.4
6	50	QT	12	22	1115	17.5	15.4	4.7
7	4.5	QT	13	29	1010	16.1	15.0	3.8
8	13	QT	9	27	1190	17.4	17.0	4.4
9	12	QT	13	29	1063	17.0	16.5	4.4
10	12	QT	14	21	1012	17.3	15.0	3.1
11	12	QT	10	27	1197	16.5	12.0	3.9
12	12	QT	14	25	1056	17.6	10.5	4.4
13	12	QT	14	27	1078	18.5	12.0	3.3
14	6	QT	12	27	1012	16.3	16.2	3.1
15	12	QT	9	27	1175	18.7	10.0	3.5
16	50	DQ-T	13	18	1015	12.0	18.0	8.8
17	12	DQ-T	16	19	1050	11.5	15.0	9.1
18	13	QT	25	18	1005	10.3	18.0	10.0
19	10	QT	22	17	1057	10.6	26.3	8.1
20	6	QT	30	18	1057	12.9	26.3	13.0
21	8	QT	16	25	631	31.5	19.4	7.4

[0048] On the basis of these results, following study is possible. First, those in Test Nos. 1-15 are the steel plates satisfying the factors stipulated in the present invention (invented steel), and it is understood that all of them show high tensile strength and excellent elongation. Also, it is learnt that high elongation is achievable by making their average prior γ grain size 20 μm or below and making their standard deviation σ 5 μm or below.

[0049] On the other hand, those in Test Nos. 16-20 are lacking either of the factors stipulated in the present invention (reference steel), and all of them have small elongation values. More specifically, those in Test Nos, 16, 17 are manufactured by DQ-T method, and although the average prior γ grain sizes are controlled small, variation of the structure attributed to uneven cooling in the accelerated cooling process occurs, therefore variation of the prior γ grain size occurs (the value of the standard deviation σ is large), consequently the desired elongation cannot be secured.

[0050] Those in Test Nos. 18-20 are the steel plates of the component base not containing Nb and Ti which affect refinement of the crystal grain size and uniformization of the structure, refinement of the prior γ grain size by carbonitride of Nb and Ti is not possible, and the longest interpass time and the draft in the finish rolling are not adjusted appropriately, therefore variation of the prior γ grain size becomes large also because of variation of growth of recrystallized grains, and high elongation cannot be achieved.

[0051] In the steel plate of Test No. 21, Mo and Nb are out of the stipulated range, therefore strength is not enough, and the condition of the longest interpass time is not satisfied, consequently variation of the prior γ grain size is large.

Claims

1. A high strength steel plate containing;
C: 0.1-0.25% (means mass%, hereinafter the same with respect to the chemical componential composition), Si: 0.1-0.5%, Mn: 0.5-2.0%, Cr: 0.1-1.5%, Mo: 0.1-0.5%, Ti: 0.01-0.05%, and Nb: 0.01-0.05% respectively, and containing at least either one of V: 0.01-0.05% and B: 0.0001-0.005%, and the balance comprising iron with inevitable impurities, wherein
the average grain size of prior austenite is 20 μm or below, the standard deviation (σ) of the prior austenite grain size distribution is 5 μm or below, and
the tensile strength is 980 MPa or above.

2. The high strength steel plate as set forth in Claim 1 further containing Ca: 0.0005-0.01%.

FIG. 1

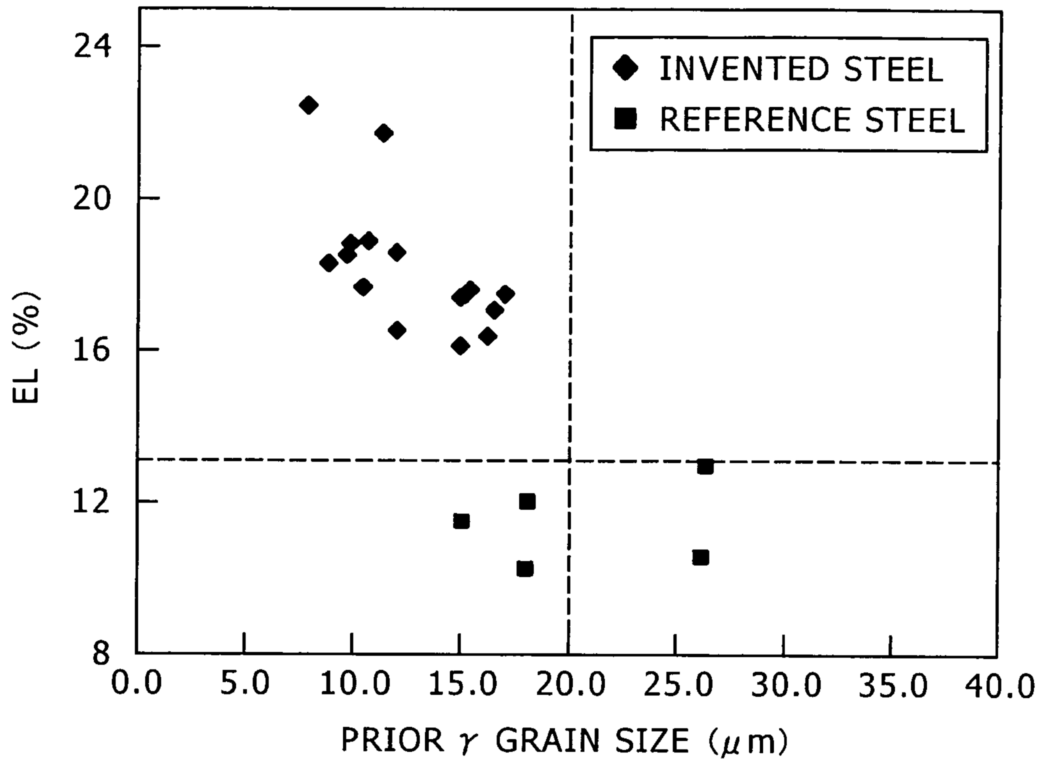
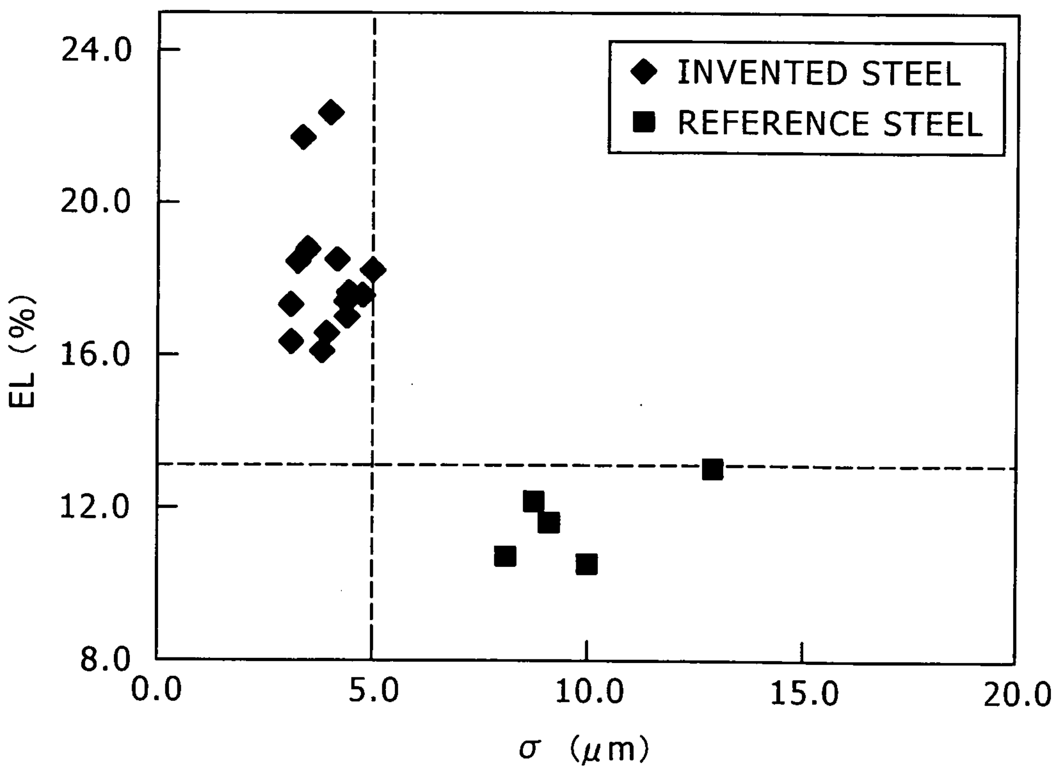

INVENTED STEEL
REFERENCE STEEL
24
20
16
12
8
EL (%)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
PRIOR γ GRAIN SIZE (μm)

FIG. 2


INVENTED STEEL
REFERENCE STEEL
24.0
20.0
16.0
12.0
8.0
EL (%)
0.0
5.0
10.0
15.0
20.0
σ (μm)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2002088440 A **[0005] [0011]**