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(54) **STEEL CONTAINING FILM TYPE RETAINED AUSTENITE**

(71) Applicant: **KOREA INSTITUTE OF MACHINERY & MATERIALS**, Daejeon (KR)

(72) Inventor: **Chang-Hoon Lee**, Changwon-si (KR)

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(57) **ABSTRACT**

The present invention relates to a steel having a microstructure composed of bainite and retained austenite, wherein the area ratio of the retained austenite 10% or more, and the retained austenite is composed of a film type retained austenite whose length is more than 3 times the width and a block type retained austenite whose length is less than 3 times the width, and wherein the area of the film type retained austenite is 60% or more of the total area of the retained austenite. The steel of the present invention can exhibit excellent strength and elongation.

Fig. 1

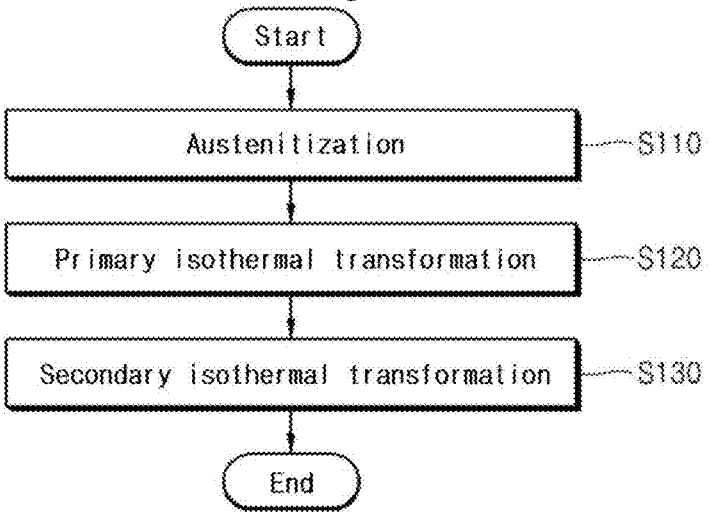


Fig. 2

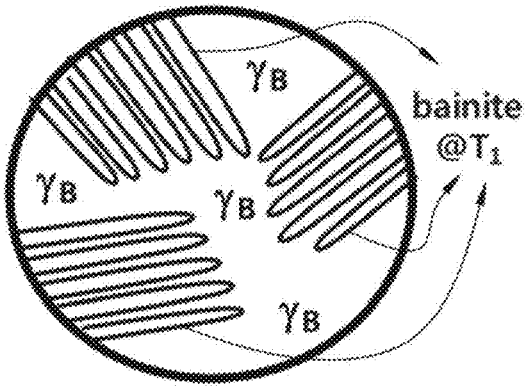


Fig. 3

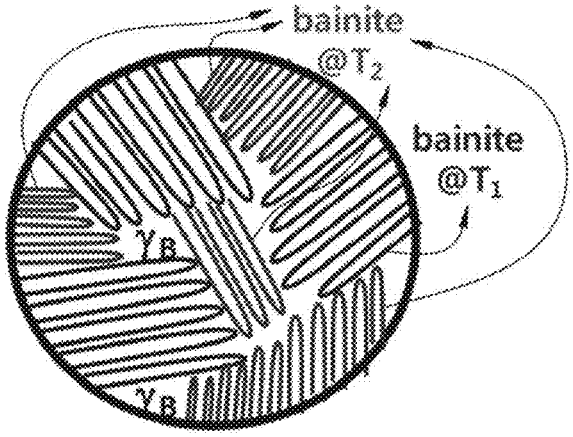


Fig. 4

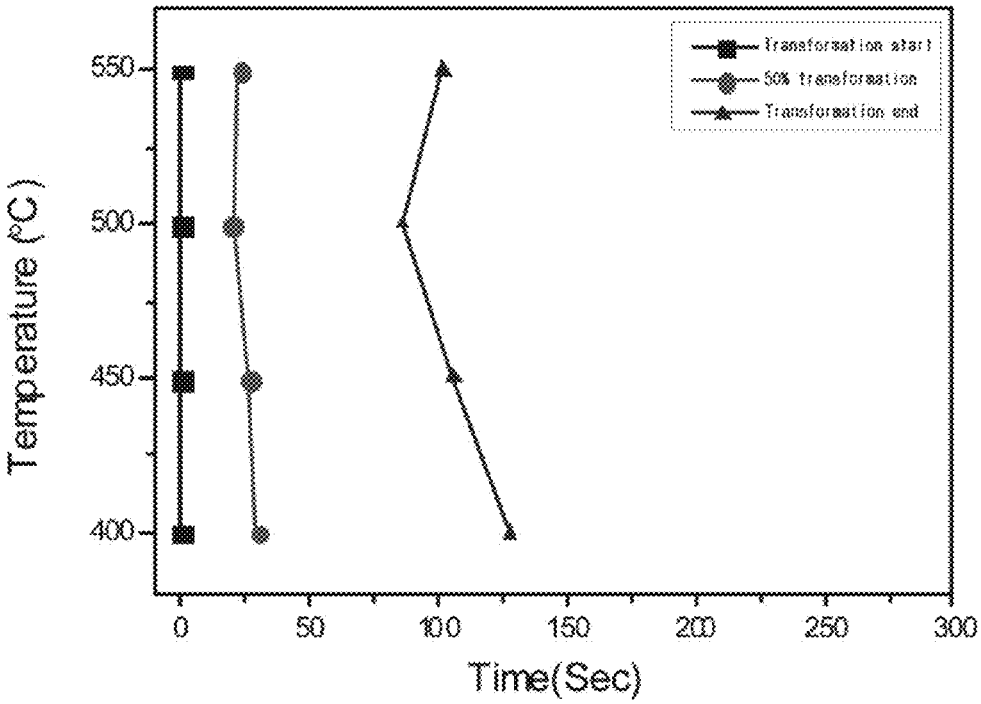

Transformation start
50% transformation
Transformation end
Temperature (°C)
550
500
450
400
0
50
100
150
200
250
300
Time(Sec)

Fig. 5

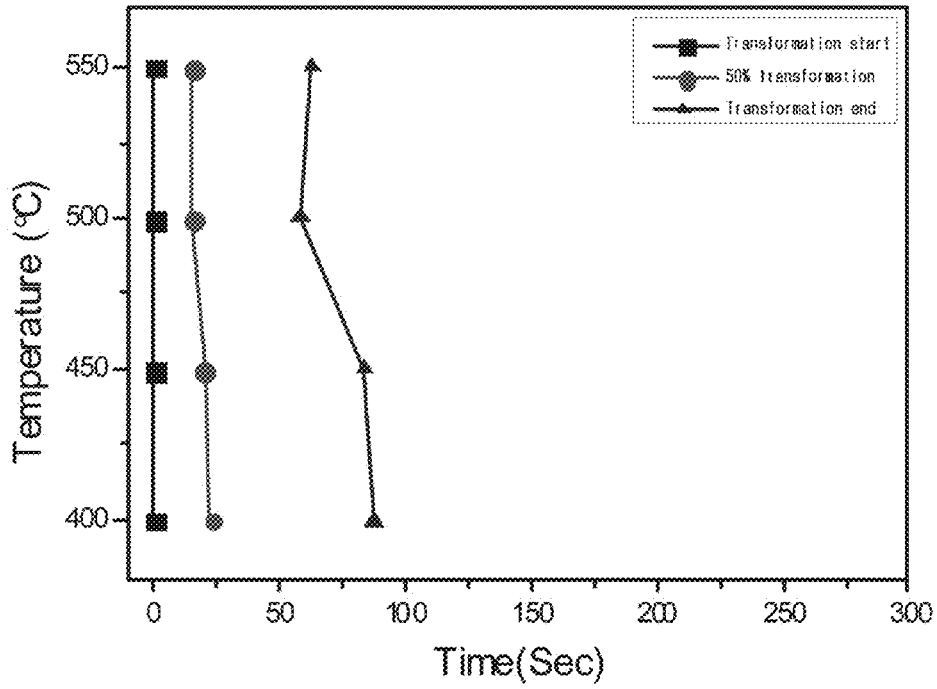

Transformation start
50% transformation
Transformation end
Temperature (℃)
550
500
450
400
0
50
100
150
200
250
300
Time(Sec)

Fig. 6

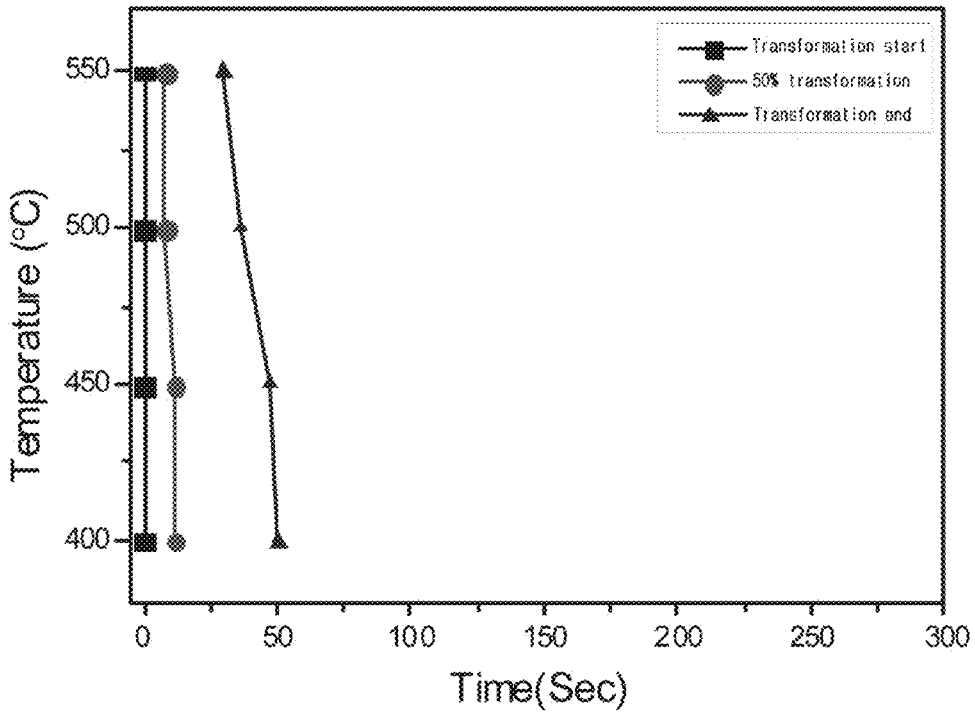

Transformation start
50% transformation
Transformation end
Temperature (°C)
550
500
450
400
0
50
100
150
200
250
300
Time(Sec)

Fig. 7A

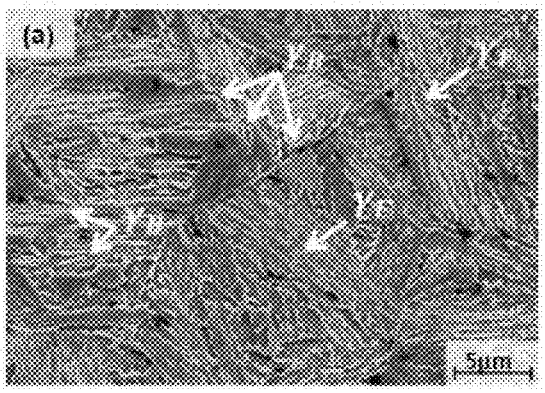

(a)
5μm

Fig. 7B

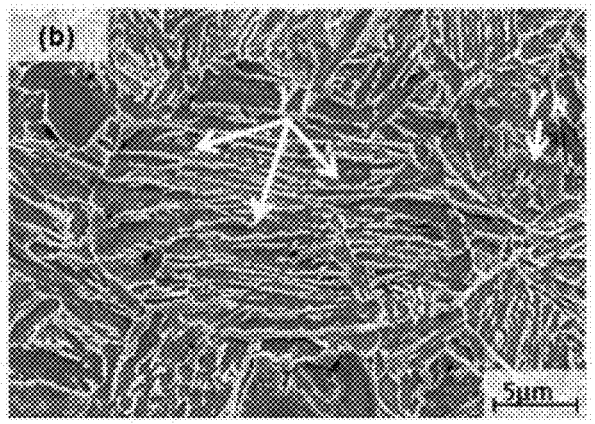

(b)
5μm

Fig. 8

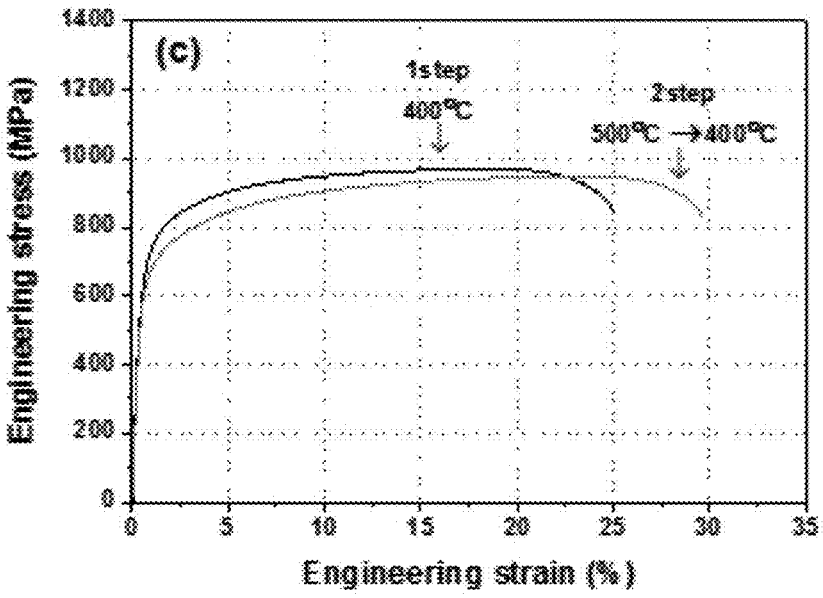

(c)
1step
400℃
2step
500℃ → 400℃
Engineering stress (MPa)
Engineering strain (%)
0
200
400
600
800
1000
1200
1400
0
5
10
15
20
25
30
35

Fig. 9A

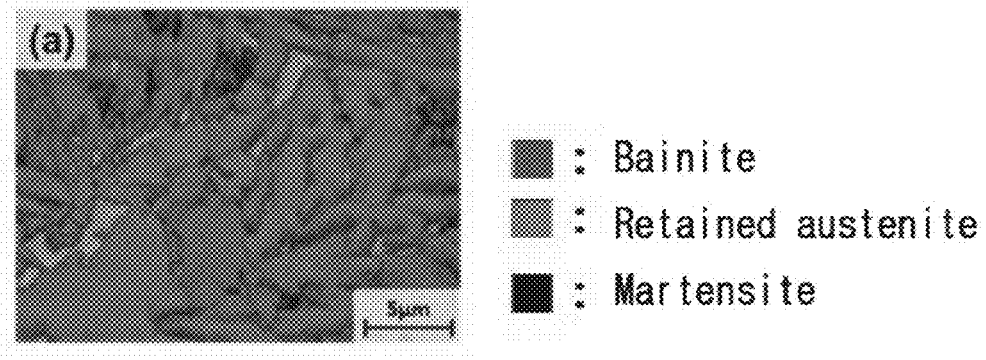


Fig. 9B

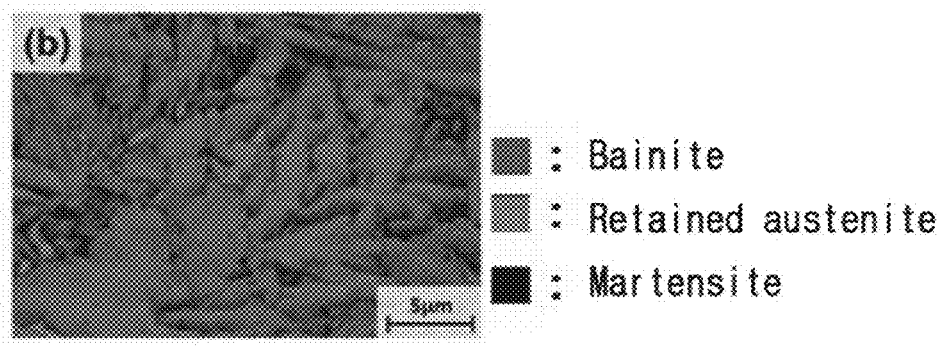


Fig. 9C

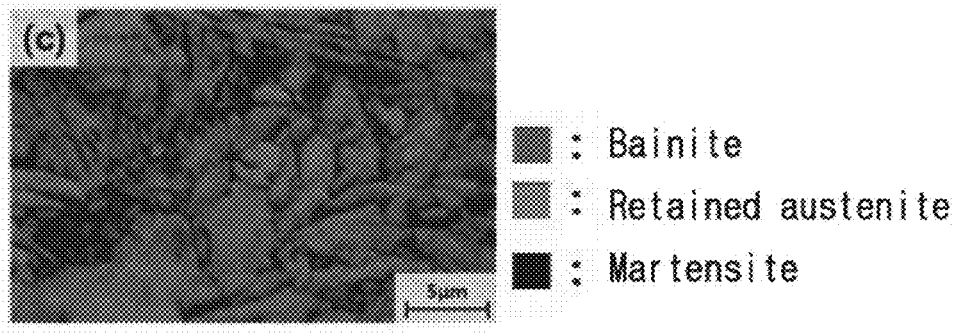


Fig. 9D

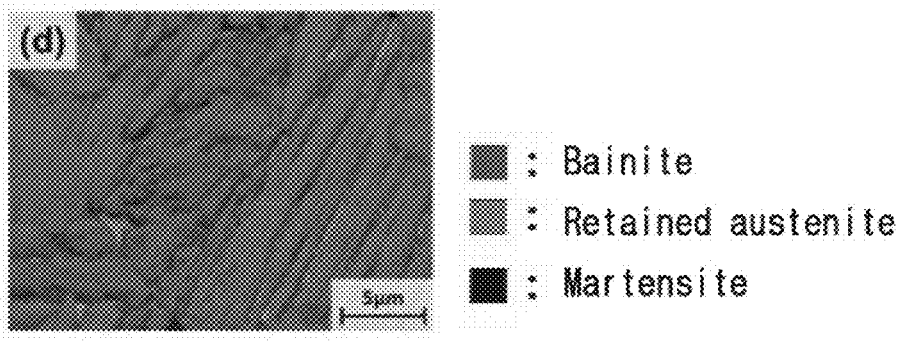


Fig. 9E

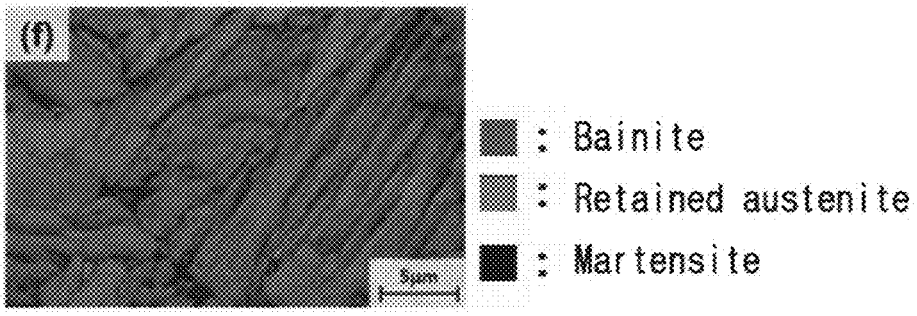


Fig. 9F

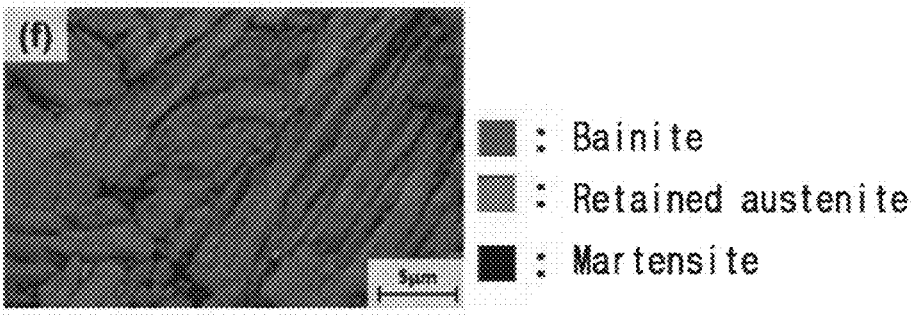


Fig. 9G

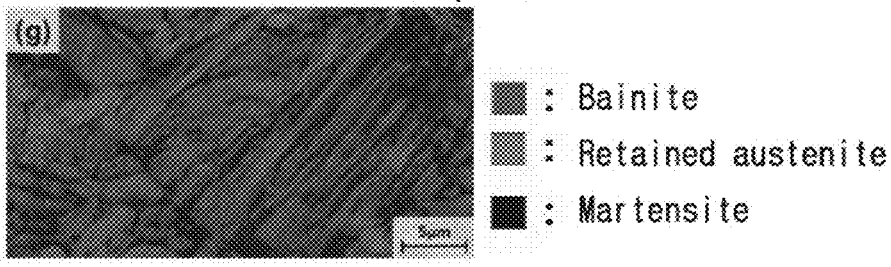
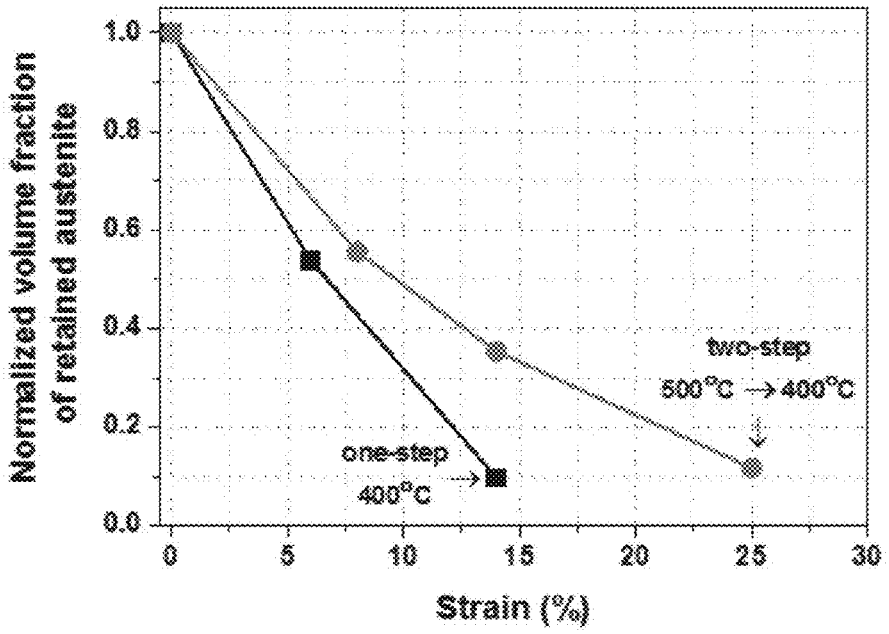


Fig. 10


Normalized volume fraction of retained austenite
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Strain (%)
two-step
500°C → 400°C
one-step
400°C

STEEL CONTAINING FILM TYPE RETAINED AUSTENITE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority of Korean Patent Application No. 10-2016-0080211 filed on Jun. 27, 2016, in the Korean Intellectual Property Office, the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a steel, and more particularly to a steel containing a large amount of film type retained austenite.

2. Description of the Related Art

[0003] Transformation induced plasticity (TRIP) steel is a type of steel alloy which exhibits improved strength and ductility while metastable austenite structure retained in a steel is transformed to martensite by plastic deformation applied from the outside.

[0004] In the case of general steels, the elongation decreases as the strength increases, and the strength decreases as the elongation increases, but in the case of TRIP steels, both strength and elongation are excellent.

[0005] The process of forming metastable retained austenite required for the transformation induced plasticity is as follows. When a steel composed of ferrite and pearlite as a basic structure and having a proper amount of Mn and Si is maintained at a proper temperature between Ac1 and Ac3 where ferrite and austenite coexist, the austenite stabilizing element in steel, particularly carbon, mostly enters into solid solution in austenite. When this is subjected to an isothermal transformation treatment of quenching into a bainite transformation region having a lower temperature than that of a pearlite transformation region and then maintaining for a few minutes, carbon diffuses and moves from ferrite to austenite while a pro-eutectoid ferrite is formed in the austenite, thereby increasing the carbon concentration in the austenite. Accordingly, Ms point as the martensitic transformation initiation temperature of the austenite can be lowered upto the room temperature or lower, and thus the austenite can retain stably without being transformed into martensite even at room temperature. When plastic deformation is applied to a steel containing such retained austenite, the plastic deformation at this time acts as a mechanical driving force, and the retained austenite is transformed into martensite, and the necking is delayed due to an increase in work hardening rate caused by martensitic transformation, thereby increasing both strength and ductility.

[0006] As the background art related to the present invention, Korean Laid-open Patent Publication No. 10-2011-0100868 (published on Sep. 15, 2011) discloses a high strength cold-rolled steel sheet excellent in tensile strength, yield strength and elongation.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a steel containing a large amount of film type retained austenite.

[0008] In order to achieve the above object, the steel according to the present invention has a microstructure composed of bainite and retained austenite, wherein the area ratio of the retained austenite is 10% or more, and the retained austenite is composed of a film type retained austenite whose length is more than 3 times the width and a block type retained austenite whose length is less than 3 times the width, and wherein the area of the film type retained austenite is 60% or more of the total area of the retained austenite.

[0009] The retained austenite can be classified into a block type retained austenite and a film type retained austenite. In this specification, the retained austenite whose length is less than three times the width is defined as a block type retained austenite, and the retained austenite whose length is more than three times the width is defined as a film type retained austenite.

[0010] Due to isothermal transformation treatment in the bainite region mentioned above, the retained austenite contains some film type retained austenite, but is mostly a block type retained austenite.

[0011] The block type retained austenite is relatively coarse and the supersaturated carbon concentration is also relatively low. Therefore, there is a problem that it may be transformed to martensite even at a small strain level. On the other hand, since the film type retained austenite has relatively fine and the supersaturated carbon concentration is relatively high, it is possible to obtain the effect of retarding the martensitic transformation even at a large strain level.

[0012] In addition, the steel may include, on a weight percentage C: 0.2~0.5%, Si: 1.0~3.0%, and Mn: 1.0~3.0%, and the balance being Fe and unavoidable impurities.

[0013] Moreover, the steel may include, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0~3.0%, and Mn: 1.0~3.0%, and further include at least one of P: 0.1% or less, S: 0.1% or less, Al: 0.5% or less, and N: 0.02% or less, or further include at least one of Cr: 3.0% or less, Mo: 1.0% or less, B: 0.005% or less, Nb: 0.1% or less, V: 0.5% or less, Ti: 0.1% or less and Ca: 0.005% or less, and the balance being Fe and unavoidable impurities.

[0014] Further, the steel may include, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0% or less, Mn: 1.0~3.0%, and Al: 0.5~2.0%, and the balance being Fe and unavoidable impurities.

[0015] Further, the steel may include, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0% or less, Mn: 1.0~3.0%, and Al: 0.5~2.0%, and further include at least one of P: 0.1% or less, S: 0.1% or less and N: 0.02% or less, or further include at least one of Cr: 3.0% or less, Mo: 1.0% or less, B: 0.005% or less, Nb: 0.1% or less, V: 0.5% or less, Ti: 0.1% or less and Ca: 0.005% or less, and the balance being Fe and unavoidable impurities.

[0016] The steel according to the present invention contains a large amount of film type retained austenite. Therefore, the steel according to the present invention is relatively excellent in strength and ductility compared to a conventional steel mainly including a block type retained austenite.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a flow chart schematically illustrating a method of manufacturing a steel according to the present invention.

[0018] FIG. **2** is a diagram conceptually showing that bainite is formed as a result of primary isothermal transformation.

[0019] FIG. **3** is a diagram conceptually showing that bainite is additionally formed as a result of secondary isothermal transformation.

[0020] FIG. **4** shows an isothermal transformation diagram of steel type 1.

[0021] FIG. **5** shows an isothermal transformation diagram of steel type 2.

[0022] FIG. **6** shows an isothermal transformation diagram of steel type 3.

[0023] FIG. **7**A shows the microstructure of specimen 11, and FIG. **7**B shows the microstructure of specimen 12.

[0024] FIG. **8** shows the strain-stress curves of the specimen 11 and specimen 12.

[0025] FIGS. **9**A to **9**C show EBSD results strains of specimen 11 at various strains, and FIGS. **9**D to **9**G show EBSD results strains of specimen 12 at various strains.

[0026] FIG. **10** shows the normalized volume fraction of retained austenite at various strains.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Hereinafter, the steel containing film type retained austenite according to the present invention will be described with reference to the accompanying drawings.

[0028] The high strength steel sheet according to the present invention has a microstructure composed of bainite and retained austenite. At this time, the retained austenite has an area ratio of 10% or more, and the bainite has an area ratio of 90% or less

[0029] In addition, the retained austenite is composed of a film type retained austenite and a block type retained austenite.

[0030] In the present invention, the film type retained austenite refers to retained austenite in which the length is at least three times the width, more specifically, the maximum length is at least three times the maximum width, when the length is greater than the width. In addition, the block type retained austenite refers to retained austenite other than film type retained austenite, i.e., retained austenite whose length is less than three times the width.

[0031] The block type retained austenite is relatively coarse and the supersaturated carbon concentration is also relatively low. Therefore, there is a problem that it is transformed to martensite even at a small strain level. On the other hand, since the film type retained austenite is relatively fine and the supersaturated carbon concentration is relatively high, the effect of retarding the martensitic transformation even at a large strain level can be obtained.

[0032] Herein, in the high strength steel sheet according to the present invention, the area of the film type retained austenite is larger than that of the block type retained austenite, and particularly, the area of the film type retained austenite is 60% or more of the total area of the retained austenite. As described above, since the steel sheet according to the present invention contains the film type retained austenite in an amount of 60% or more of the total retained austenite, the martensitic transformation can be retarded even at a large strain level compared to a conventional block type retained austenite-based steel, and thus, the strength and elongation can be greatly improved.

[0033] The microstructural features of the steel according to the present invention can be achieved by a manufacturing method including a multi-stage isothermal transformation in a bainite region described later.

[0034] The steel according to the present invention can be applied without limitation as long as it is a steel sheet having an alloy composition that can contain a retained austenite in the final microstructure, and more preferably, a steel having an alloy composition that can stably secure the area ratio of the retained austenite by 10% or more can be presented. In addition, the shape of the steel sheet before heat treatment may be a hot rolled steel sheet or a cold rolled steel sheet, more preferably a cold rolled steel sheet.

[0035] The high strength steel sheet according to a first preferred embodiment of the present invention may contain, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0~3.0%, and Mn: 1.0~3.0%, and the balance being F and unavoidable impurities.

[0036] Further, the high strength steel sheet according to a first preferred embodiment of the present invention may further contain, on a weight percentage basis, at least one of P: 0.1% or less, S: 0.1% or less, Al: 0.5% or less and N: 0.02% or less instead of Fe. Furthermore, the high strength steel sheet according to the embodiment may further contain, on a weight percentage basis, at least one of Cr: 3.0% or less, Mo: 1.0% or less, B: 0.005% or less, Nb: 0.1% or less, V: 0.5% or less, Ti: 0.1% or less and Ca: 0.005% or less instead of Fe.

[0037] Carbon (C) is an element for forming a large amount of retained austenite in the steel sheet. The carbon is preferably contained in an amount of 0.2 to 0.5% by weight based on the total weight of the steel sheet. When the content of carbon is less than 0.2% by weight, it may be difficult to secure at least 10% of retained austenite in the final microstructure. Conversely, when the content of carbon exceeds 0.5% by weight, the weldability may be reduced.

[0038] Silicon (Si) contributes to concentrating a carbon in the retained austenite by suppressing the formation of carbides, thereby increasing the thermomechanical stability of austenite. Silicon acts as a deoxidizer in the steel. Further, the silicon stabilizes the ferrite and thus contributes to strength. Further, silicon promotes the austenite-ferrite transformation and thus serves to increase the ferrite fraction. In the present embodiment, silicon is preferably contained in an amount of 1.0 to 3.0% by weight based on the total weight of the steel sheet. When the content of silicon exceeds 1.0% by weight, the effect due to the addition is insufficient. Conversely, when the content of silicon exceeds 3.0% by weight, the weldability and the plating property may be lowered.

[0039] Manganese (Mn) contributes to stabilization of austenite and improvement of strength. The manganese is preferably added in an amount of 1.0 to 3.0% by weight based on the total weight of the steel sheet. When the addition amount of manganese is less than 1.0% by weight, the effect due to the addition thereof is insufficient. On the other hand, when the addition amount of manganese exceeds 3.0% by weight, it may arise problems in terms of oxidation scale and plating property.

[0040] On the other hand, the high strength steel sheet according to the present invention may further contain phosphorus (P), sulfur (S), nitrogen (N), aluminum (Al), chromium (Cr), molybdenum (Mo), boron (B), niobium (Nb), vanadium (V), titanium (Ti), calcium (Ca) and the like

as impurities or for the purpose of improving strength. The phosphorus (P), sulfur (S) and nitrogen (N) contribute partially to strength, workability, crystal grain refinement, and the like. However, when they are contained in large amounts, it causes toughness, crack generation and the like. In the case of Al, it can be added as a deoxidizer. Therefore, when these elements are included, the content thereof limited to P: 0.1 wt % or less, S: 0.1 wt % or less, Al: less than 0.5 wt %, and N: 0.02 wt % or less based on the total weight of the steel sheet. Further, elements such as chromium (Cr), molybdenum (Mo), boron (B), niobium (Nb), vanadium (V) and titanium (Ti) contribute to the improvement of the strength of steel through work hardening, precipitation hardening or the like, and calcium (Ca) contributes to the purification of steel by spheroidizing the inclusions. However, if these components are excessive, the combination of strength and elongation may rather decrease due to a decrease elongation or the effect may be saturated. Therefore, the content thereof is limited to Cr: 3.0 wt % or less, Mo: 1.0 wt % or less, B: 0.005 wt % or less, Nb: 0.1 wt % or less, V: 0.5 wt % or less, Ti: 0.1 wt % or less and Ca: 0.005 wt % or less.

[0041] The high strength steel sheet according to the second preferred embodiment of the present invention contains, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0% or less, Mn: 1.0~3.0%, and Al: 0.5~2.0%, and the balance being F and unavoidable impurities.

[0042] Further, the high strength steel sheet according to the second embodiment of the present invention may further contain, on a weight percentage basis, at least one of P: 0.1% or less, S: 0.1% or less and N: 0.02% or less instead of Fe. Furthermore, the high strength steel sheet according to the embodiment may further contain, on a weight percentage basis, at least one of Cr: 3.0% or less, Mo: 1.0% or less, B: 0.005% or less, Nb: 0.1% or less, V: 0.5% or less, Ti: 0.1% or less and Ca: 0.005% or less instead of Fe.

[0043] The high strength steel sheet according to the second embodiment does not contain silicon or, instead of being contained at 1.0% by weight or less, contains 0.5 to 2.0% by weight of aluminum (Al).

[0044] In the high strength steel sheet according to the second embodiment, the silicon is preferably contained in an amount of 1.0% by weight or less based on the total weight of the steel sheet. This considers that aluminum (Al) is included in an amount of 0.5 to 2.0% by weight in the case of this embodiment. When the content of silicon exceeds 1.0% by weight in this embodiment, the weldability and plating properties may be lowered.

[0045] Aluminum (Al) generally acts as a deoxidizer, but aluminum in the high strength steel sheet according to the second embodiment promotes the austenite-bainite phase transformation, thereby improving the productivity. The aluminum is preferably contained in an amount of 0.5 to 2.0% by weight based on the total weight of the steel sheet. When the addition amount of aluminum is less than 0.5% by weight, the effect of improving the productivity may be insufficient. On the contrary, when the addition amount of aluminum exceeds 2.0% by weight, the surface quality of the steel sheet may be problematic.

[0046] On the other hand, in the high strength steel sheet according to the second embodiment, those where silicon and aluminum are $Si \leq Al$, $Si+Al \leq 2.5$ wt % are more preferable in view of surface quality and plating properties.

[0047] Further, the high strength steel sheet according to the second embodiment may further contain phosphorus (P), sulfur (S), nitrogen (N), chromium (Cr), molybdenum (Mo), boron (B), niobium (Nb), vanadium (V), titanium (Ti), calcium (Ca), and the like as impurities or for the purpose of improving the strength. The phosphorus (P), sulfur (S) and nitrogen (N) contribute partially to strength, workability, crystal grain refinement, and the like. However, when they are contained in large amounts, it causes toughness, crack generation and the like. Therefore, when these elements are included, the content thereof is limited to P: 0.1 wt % or less, S: 0.1 wt % or less, and N: 0.02 wt % or less based on the total weight of the steel sheet. Further, elements such as chromium (Cr), molybdenum (Mo), boron (B), niobium (Nb), vanadium (V) and titanium (Ti) contribute to the improvement of the strength of steel through work hardening, precipitation hardening or the like, and calcium (Ca) contributes to the purification of steel by spheroidizing the inclusions. However, if these components are excessive, the combination of strength and elongation may rather decrease due to a decrease in elongation or the effect may be saturated. Therefore, the content thereof is limited to Cr: 3.0 wt % or less, Mo: 1.0 wt % or less, B: 0.005 wt % or less, Nb: 0.1 wt % or less, V: 0.5 wt % or less, Ti: 0.1 wt % or less and Ca: 0.005 wt % or less based on the total weight of the steel sheet.

[0048] The high strength steel sheet having the alloy composition according to the first embodiment or the second embodiment may exhibit a tensile strength of 1000 MPa or more, and a product of tensile strength and elongation of 25,000 MPa·% or more, and in some examples, of 30,000 MPa·% or more, in combination with the manufacturing method described later. Furthermore, the high strength steel sheet according to the present invention may exhibit an elongation of 25% or more.

[0049] However, in the case of a steel having a C content of less than 0.2% by weight and a Mn content of less than 1.0% by weight, the hardenabilty is low, and there is a high possibility that a high temperature phase such as ferrite is generated during cooling after austenitization, making it difficult to secure a pure bainite structure. Therefore, a steel having a C content of 0.2% by weight or more and a Mn content of 1.0% by weight or more can be preferably applied to the present invention.

[0050] FIG. **1** is a flow chart schematically illustrating a method of manufacturing a steel according to the present invention.

[0051] Referring to FIG. **1**, a method for manufacturing a high strength steel sheet according to an embodiment of the present invention includes austenitization step (S**110**), a primary isothermal transformation step (S**120**) and a secondary isothermal transformation step (S**130**). The feature of this method is that both a primary isothermal transformation and a secondary isothermal transformation are carried out at a temperature higher than the bainite region, i.e., the martensitic transformation temperature.

[0052] In the austenitization step (S**110**), the steel sheet is heated and austenitized. Through this, the microstructure can be fully austenitized.

[0053] The steel sheet can be applied without limitation as long as it is a steel sheet having an alloy composition capable of containing retained austenite the final microstructure. More preferably, a steel having an alloy composition capable of stably securing the area ratio of the retained

austenite by 10% or more can be presented. The type of the steel sheet before heat treatment may be a hot rolled steel sheet or a cold rolled steel sheet, more preferably a cold rolled steel sheet.

[0054] The austenitization can be carried out by a method of maintaining at Ac3~Ac3+200° C. for 1 minute or more, for example, for example 1 to 30 minutes. When the austenitizing temperature is lower than Ac3, a large amount of ferrite retains, and when the austenitizing temperature exceeds Ac3+200° C., the crystal grain size may excessively increase. In addition, when the austenitization time is less than one minute, austenitization may be insufficient.

[0055] Next, in the primary isothermal transformation step (S**120**), the austenitized steel sheet is primarily cooled to T1 corresponding to the bainite region, and subjected to primary isothermal transformation. Here, the bainite region means a temperature region which ranges from Bs or less which is the bainite transformation start temperature to Ms or more which is the martensite transformation start temperature.

[0056] Here, the primary isothermal transformation may be carried out at T1, but it is not necessarily limited thereto, and may be performed at a temperature lower by about 10° C. than T1, depending on process facility conditions and the like. These concepts can be similarly applied to a secondary isothermal transformation described later.

[0057] As a result of the primary isothermal transformation in the bainite region, a part of austenite transforms into bainite, more specifically lath-shaped bainite, as in the example shown in FIG. **2**. Austenite remains in the form of a film between the bainites, but in the part where the bainites are not formed, austenite generally remains in the form of a block.

[0058] In the primary isothermal transformation, the bainite transformation can be carried out to have an area ratio of 30 to 70%. This considers the formation of film type retained austenite between lath-shaped bainites and the formation of retained austenite having an area ratio of at least 10% after the secondary isothermal transformation.

[0059] The average cooling rate during the primary cooling can be applied at an average cooling rate of 20° C./sec or more, more preferably 50 to 100° C./sec, in order to suppress the occurrence of phase transformation such as ferrite as much as possible.

[0060] Next, in the secondary isothermal transformation step (S**130**), the steel sheet subjected to the primary isothermal transformation is secondarily cooled upto T2 which corresponds to the bainite region, but is more than 50° C. lower than T1, at an average cooling rate of 20° C./sec or more, for example, 20 to 100° C./sec, and subjected to secondary isothermal transformation. After the second isothermal transformation, the final cooling can be carried out by a method such as air cooling, water cooling, or the like. The final cooling can be carried out up to room temperature.

[0061] As a result of the secondary isothermal transformation in the bainite region, a part of the retained austenite is additionally transformed into bainite as in the example shown in FIG. **3**. In this process, bainite is formed from austenite in the form of a block, and the volume faction of the film type retained austenite increases.

[0062] Herein, the reason why the secondary isothermal transformation temperature is lower than the primary isothermal transformation temperature by 50° C. or more is that, when the temperature difference between the second isothermal transformation temperature and the first isothermal transformation temperature is lower than 50° C., the strength remarkably decreases and thus the combination of strength and elongation was not good.

[0063] That is, in the case of the present invention, austenite phase-transformed into bainite in primary isothermal transformation, and film type austenite and block type austenite retian, especially in the case of the secondary isothermal transformation, the block type austenite formed in the primary isothermal transformation is additionally transformed into bainite, whereby the volume fraction of the film type retained austenite increases.

[0064] On the other hand, in the case of the steel sheet having the alloy composition according to the first embodiment, the first isothermal transformation can be carried out at 400 to 600° C. for 20 to 100 seconds. In the steel sheet containing the alloy composition described above, when T1 is lower than 400° C., the secondary isothermal transformation at Ms or more can be difficult. In addition, when the primary isothermal transformation time is less than 20 seconds, bainite may not be sufficiently formed, and when 100 seconds have elapsed, it may be difficult to form the retained austenite having an area ratio of 10% or more after secondary isothermal transformation.

[0065] Moreover, it is desirable to conduct secondary isothermal transformation for at least 100 seconds in order to form sufficient bainite during the second isothermal transformation. In addition, the second isothermal transformation is carried out at a temperature 50° C. lower than the first isothermal transformation temperature. Then, the second isothermal transformation can be carried out for 100 seconds or more, more preferably 100 to 150 seconds. Through the second isothermal transformation of 100 seconds or more, the volume fraction of the film type austenite in the retained austenite can be maximized through the lath-shaped additional bainite transformation

[0066] On the other hand, in the case of the steel sheet having the alloy composition according to the second embodiment, the first isothermal transformation can be carried out at 400 to 600° C. for 3 to 25 seconds. In the case of the present invention, as a result of the addition of 0.5% by weight or more of aluminum, the austenite-bainite phase transformation is promoted and the phase transformation time can be reduced within 25 seconds. When the first isothermal transformation time is less than 3 seconds, bainite may not be formed sufficiently. Conversely, when the primary isothermal transformation time exceeds 25 seconds, it is difficult to form retained austenite having an area ratio of 10% or more after the second isothermal transformation.

[0067] In addition, in order to form sufficient bainite during the second isothermal transformation, it is desirable to conduct a second isothermal transformation for 40 seconds or more, more preferably for 40 to 80 seconds. In the case of having the alloy composition according to the first embodiment, the secondary isothermal transformation is required for about 100 seconds or more, whereas in the case of having the alloy composition according to the second embodiment, the secondary isothermal transformation time can be reduced by 40 seconds or more due to the effect caused by the addition of aluminum.

EXAMPLE

[0068] Hereinafter, the configuration and operation of the present invention will be described in more detail through

preferred examples of the present invention. However, these examples are presented for illustrative purposes only, and it should be understood that the present invention is limited thereto in any way.

[0069] The contents not described here can be inferred sufficiently technically by those skilled in this technical field, and thus a description thereof will be omitted.

[0070] 1. Manufacture of Steel Sheet Specimen

[0071] Cold rolled steel sheet specimens having the alloy components listed in Table 1 below were austenitized at 900° C. for 10 minutes and primarily cooled to the primary isothermal transformation temperature shown in Table 2 at an average cooling rate of 60° C./sec, followed by secondary cooling to the secondary isothermal transformation temperature shown in Table 2 at an average cooling rate of 25° C./sec. After that, the secondary isothermal transformation was carried out for 100 seconds, and finally cooled to 25° C. at an average cooling rate of 30° C./sec. Thereby the steel specimens 1 to 8 were prepared.

TABLE 1

Steel type	C	Si	Mn	Remarks
1	0.18	1.5	2.1	Comparative steel
2	0.36	1.1	2.1	Inventive steel
3	0.41	1.5	2.0	Inventive steel
4	0.40	0.5	2.2	Comparative steel

TABLE 2

Specimen	Steel type	Primary isothermal transformation (° C.)	Secondary isothermal transformation (° C.)	Classification
1	1	500	400	Comparative steel 1
2	2	500	400	Inventive steel 1
3	2	500	460	Comparative steel 2
4	3	400	—	Comparative steel 3
5	3	450	420	Comparative steel 4
6	3	450	400	Inventive steel 2
7	3	450	350	Inventive steel 3
8	4	450	400	Comparative steel 5

[0072] Further, the cold-rolled steel sheet specimens having alloy components listed in Table 3 below were austenitized at 900° C. for 10 minutes, primarily cooled upto the primary isothermal transformation temperature shown in Table 4 at an average cooling rate of 60° C./sec and then subjected to primary isothermal transformation at that temperature. After that, the secondary cooling was carried out upto the secondary isothermal transformation temperature shown in Table 2 at an average cooling rate of 25° C./sec and subjected to secondary isothermal transformation for 60 seconds, and then finally cooled upto 25° C. at an average cooling rate of 30° C./sec. Thereby the steel sheet specimens 9 to 10 were prepared.

TABLE 3

Steel type	C	Si	Mn	Al	Remarks
5	0.31	0.7	2.0	0.8	Inventive steel
6	0.29		2.0	1.5	Inventive steel

TABLE 4

Specimen	Steel type	Primary isothermal transformation (° C.)	Primary isothermal transformation-maintaining time	Secondary isothermal transformation (° C.)	Classification
9	5	450	15 sec	400	Inventive steel
10	6	450	10 sec	400	Inventive steel

[0073] 2. Microstructure and Physical Property Evaluation

[0074] The fraction of the retained austenite was calculated for the prepared steel sheet specimens 1 to 10 through the analysis of SEM photograph and TEM photograph, and those whose maximum length was 3 times or more the maximum width was defined as a film type retained austenite. In addition, tensile strength and elongation were measured by conducting a tensile test on the prepared steel sheet specimens.

[0075] The results are shown in Table 5 below.

[0076] In Table 5, the γ fraction means the fraction of the retained austenite, and f-γ fraction means the fraction of a film type retained austenite in the retained austenite.

TABLE 5

Specimen	Steel type	Tensile strength (Mpa)	Elongation (%)	Tensile strength* Elongation (MPa %)	γ fraction (%)	f-γ fraction (%)	Classification
1	1	1007	18	18,126	9	72	Comparative Steel 1
2	2	1012	29	29,348	12	68	Inventive Steel 1
3	2	920	23	21,160	15	58	Comparative Steel 2
4	3	1148	18	20,664	8	51	Comparative Steel 3
5	3	985	28	27,580	12	53	Comparative Steel 4
6	3	1051	31	32,581	15	73	Inventive Steel 2
7	3	1064	28	29,792	14	78	Inventive Steel 3
8	4	1018	23	23,414	7	67	Comparative Steel 5
9	5	1012	31	31,372	15	65	Invention Steel 4
10	6	1037	29	30,072	13	67	Invention Steel 5

[0077] Referring to Table 5, in the case of the specimens 2, 6, 7, 9 and 10 in which the retained austenite volume fraction was in an area ratio of 10% or more and the film type retained austenite volume fraction in the retained austenite was 60% or more, it was shown that a tensile strength was 1000 MPa or more, a product of tensile strength and elongation was 25,000 MPa·% or more, and an elongation was 25% or more.

[0078] On the other hand, in the case of the specimens 1, 3, 4, 5, and 8 in which the retained austenite volume fraction was in an area ratio of less than 10% or the film type retained austenite volume fraction in the retained austenite was less than 60%, it was shown that the tensile strength was less than 1000 MPa or a product of tensile strength and elongation was less than 25,000 MPa·%. This was because the retained austenite had the alloy composition that cannot be produced by 10% or more, or two-stage isothermal transformation was not carried out, or the transformation temperature difference was less than 50° C. even if two-stage isothermal transformation was carried out.

[0079] FIG. **4** shows an isothermal transformation diagram of steel type 2. FIG. **5** shows an isothermal transformation diagram of steel type 5. FIG. **6** shows an isothermal transformation diagram of steel type 6. Referring to FIGS. **4** to **6**, it could be seen that in the case of the steel type 5 and the steel type 6 in which Al was added by 0.5 wt % or more, the transformation time is greatly reduced, as compared with the steel type 2 in which Al was not added.

[0080] As a result, in the case of the specimens 9 and 10, the produced steel sheets could exhibit the same or better physical properties, although the isothermal transformation time was relatively short as compared with the specimens 2, 6, and 7, and thus it could be seen to be more desirable in terms of productivity.

[0081] FIG. **7**A shows the microstructure of specimen 11, and FIG. **7**B shows the microstructure of specimen 12. specimen 12. FIG. **8** shows the strain-stress curves of the specimen 11 and specimen 12.

[0082] The specimen 11 of FIG. **7**A and the specimen 12 of FIG. **7**B were manufactured by the following procedure.

[0083] The cold-rolled steel sheet specimen having the composition of steel grade 2 was austenitized at 950° C. for 5 minutes, cooled upto 400° C. at an average cooling rate of 20° C./sec and then subjected to isothermal transformation for seconds. Then, water-quenching was carried out to prepare specimen 11.

[0084] Also, the cold rolled steel sheet specimens having the composition of steel type 2 were austenitized at 950° C. for 5 minutes, primarily cooled upto 500° C. at an average cooling rate of 20° C./sec, subjected to primary isothermal transformation for 30 seconds, again secondarily cooled upto 400° C. at an average cooling rate of 20° C./sec and subjected to a second isothermal transformation for 100 seconds. Then, water quenching was carried out to prepare a specimen 12.

[0085] Referring to FIGS. **7**A and **7**B, it could be seen that in the microstructure (FIG. **7**A) of the specimen 11, a large number of block type retained austenite (γB) were observed, but in the microstructure of the specimen 12 (FIG. **7**B), most retained austenite was a film type retained austenite ((γF).

[0086] Further, referring to FIG. **8**, the specimen 11 and the specimen 12 showed tensile strength similar to each other, but the specimen containing a large amount of block type retained austenite showed an elongation of about 25%, whereas the specimen 12 containing a large amount of film type retained austenite showed an elongation of about 30%.

[0087] FIGS. **9**A to **9**C show EBSD results strains of specimen 11 at various strains, and FIGS. **9**D to **9**G show EBSD results strains of specimen 12 at various strains. FIG. **10** shows the normalized volume fraction of retained austenite at various strains.

[0088] FIGS. **9**A, **9**B and **9**C are for the specimen 11, and FIGS. **9**D, **9**E, **9**F and **9**G are for the specimen 12. FIG. **9**A shows a 0% strain, FIG. **9**B shows a 6% strain, FIG. **9**C shows a 14% strain, FIG. **9**D shows a 0% strain, FIG. **9**E shows a 8% strain, FIG. **9**F shows a 14% strain, and FIG. **9**G shows a 24% strain. In FIGS. **9**A to **9**G, green means bainite, red means retained austenite, and black means martensite.

[0089] Referring to FIGS. **9**A to **9**G, it can be seen that in the case of the specimen 11, a large number of block type retained austenite exists, but in the case of the specimen 12, a large number of film type retained austenite exists.

[0090] Referring to FIGS. **9**A to **9**G and **10**, it can be seen that, in the case of the specimen 11, the retained austenite is mostly transformed into martensite at the strain of up to 14% (FIGS. **9**B and **9**C). On the contrary, in the case of the specimen 12, it can be seen that the retained austenite phase is maintained without being substantially transformed into martensite at the strain of up to 14% in the case of the specimen 12 (FIGS. **9**E and **9**F). It can be seen that the transformation is made to martensite at a 25% stain (FIG. **9**G).

[0091] Although the embodiments of the present invention have been described above, various changes and modifications can be made at the level of a technician having ordinary knowledge in the technical field to which the present invention belongs. These changes and modifications can be considered as belonging to the present invention as long as they do not deviate from the technical idea provided by the present invention. Accordingly, the scope of the present invention should be determined by the claims set forth below.

What is claimed is:

1. A steel having microstructure composed of bainite and retained austenite, wherein the area ratio of the retained austenite is 10% or more, and the retained austenite composed of a film type retained austenite whose length is more than 3 times the width and a block type retained austenite whose length is less than 3 times the width, and wherein the area of the film type retained austenite is 60% or more of the total area of the retained austenite.

2. The steel of claim **1**, wherein the steel includes, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0~3.0%, and Mn: 1.0~3.0%, and the balance being Fe and.unavoidable impurities.

3. The steel of claim **1**, wherein the steel includes, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0~3.0%, and Mn: 1.0~3.0%, and further include at least one of P: 0.1% or less, S: 0.1% or less, Al: 0.5% or less, and N: 0.02% or less, or further include at least one of Cr: 3.0% or less, Mo: 1.0% or less, B: 0.005% or less, Nb: 0.1% or less, V: 0.5% or less, Ti: 0.1% or less and Ca: 0.005% or less, and the balance being Fe and unavoidable impurities.

4. The steel of claim **1**, wherein the steel on a weight percentage basis, C: 0.2~0.5%, Si: 1.0% or less, Mn: 1.0~3.0%, and Al: 0.5~2.0%, and the balance being Fe and unavoidable impurities.

5. The steel of claim **4**, wherein the steel is $Si \leq Al$, $Si+Al \leq 2.5$ wt %.

6. The steel of claim **1**, wherein the steel includes, on a weight percentage basis, C: 0.2~0.5%, Si: 1.0% or less, Mn: 1.0~3.0%, and Al: 0.5~2.0%, and further include at least one of P: 0.1% or less, S: 0.1% or less and N: 0.02% or less, or further include at least one of Cr: 3.0% or less, Mo: 1.0% or less, B: 0.005% or less, Nb: 0.1% or less, V: 0.5% or less, Ti: 0.1% or less and Ca: 0.005% or less, and the balance being Fe and unavoidable impurities.

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