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(54) An abrasion resistant steel

Abriebfester Stahl

Acier résistant à l'abrasion

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(73) Proprietor: **NKK CORPORATION**
Tokyo 100 (JP)

(72) Inventors:
- **Shikanai, Nobuo, c/o Patent & License Dept.**
  Kawasaki, 210 (JP)
- **Sanpei, Tetsuya, c/o Patent & License Dept.**
  Kawasaki, 210 (JP)
- **Yako, Kazunori, c/o Patent & License Dept.**
  Kawasaki, 210 (JP)
- **Hirabe, Kenji, c/o Patent & License Dept.**
  Kawasaki, 210 (JP)
- **Kunisada, Yasunobu, c/o Patent & License Dept.**
  Kawasaki, 210 (JP)

(74) Representative: **Watkins, David et al**
Urquhart-Dykes & Lord,
91 Wimpole Street
London W1M 8AH (GB)

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Description

The invention relates to the field of metallurgy and particularly relates to the field of an abrasion resistant steel utilized in the field of construction, civil engineering and mining.

Abrasion resistant steels are utilized in the field of construction, civil engineering and mining such as in power shovel, bulldozer, hopper and bucket to keep the lives of these machines or their parts. It is well known that the steel having high hardness possesses high abrasion resistance property. For this purpose a high alloyed steel treated by quenching has commonly been utilized.

Japanese Patent laid open Publication Nos. 142726/19 87, 169359/1988 and 142023/1989 disclose the information about the production of the conventional abrasion resistant steel. In these inventions the Brinell Hardness of the steel is more than 300. The improvements are aimed at the weldability, the toughness and the workability in bending, and the abrasion resistance property is realized by increasing the hardness of the steel.

CH-A-377540 and SU-A-271807 also relate to abrasion resistant steel compositions, consisting of: 0.15-0.3%C, 0.6-1.0%Si, 0.35-0.8% Mn, 0.1-0.6%Ti balance Fe or 0.29-0.32%C, 0.6-0.9%Si, 0.8-1.2%Mn, 0.45-0.70%Ti, balance Fe and incidental impurities, respectively.

However the property required for the abrasion resistant steel has recently become severer and the essential solution to higher abrasion resistance of steel will not be obtained by simply enhancing the hardness of steel. When the hardness of steel is significantly enhanced, the weldability and the workability of steel are deteriorated due to the high alloying and the cost of producing such steels increases significantly. Accordingly in the practical point of view the significant increase in the hardness of abrasion resistant steel is facing with a difficulty with respect to the workability of the steel.

It is an object of the invention to provide an abrasion resistant steel.

It is an object of the invention to provide an abrasion resistant steel having an excellent abrasion resistance property without considerably increasing the hardness of steel. According to the invention an abrasion resistant steel comprises 0.2 to 0.35 wt.% C, 0.1 to 1.0 wt.% Si, 0.1 to 2.0 wt.% Mn, 0.3 to 1.0 wt.% Ti and the balance Fe as the basic elements contributing to the enhancement of the abrasion resistance property.

In addition to the basic elements, at least one element selected from the group consisting of 0.1 to 2.0 wt.% Cu, 0.1 to 10.0 wt.% Ni, 0.1 to 3.0 wt.% Cr, 0.1 to 3.0 wt.% Mo and 0.0003 to 0.01 wt.% B is added to enhance the quenching hardenability of the steel, and at least one element selected from the group consisting of 0.005 to 0.5 wt.% Nb, 0.01 to 0.5 wt% V may be added to enhance the precipitation hardenability of the steel.

Figure 1 is a graph showing the relationship between the added quantity of titanium and the ratio of resistance to abrasion.

The most significant characteristic of the invented steel is effectively utilizing of very hard TiC. In this invention it is not necessary to enhance the hardness of the abrasion resistant steel only by transforming the microstructure of the steel to a martensite which is the conventional way to enhance the abrasion resistance of steel.

In the conventional way the purpose of the addition of titanium to steel is to react with the nitrogen so that the nitrogen is stabilized as TiN. As the result boron does not react with nitrogen since there is not enough nitrogen in the steel, and retained in the steel as a soluble boron, which enhances the quenching hardenability.The quantity of the addition in this case is about 0.02 wt.% of steel. The addition of a large quantity of titanium to steel is limited by the oxidation of the titanium in the steel melting stage, the clogging of the nozzle and the reaction with the oxidation preventing powder in the casting stage. Therefore the effect of the addition of a large quantity of titanium is not yet known.

The inventors after detailed examination found that the addition of titanium in a large quantity realizes the improvement of steel with respect to the abrasion resistance property.

Figure 1 is a graph showing the relationship between the added quantity of titanium and the ratio of resistance to abrasion. The abscissa denotes the added quantity of titanium and the ordinate denotes the ratio of resistance to abrasion.

The ratio of resistance to abrasion is an index wherein the resistance to abrasion of an abrasion resistant steel is divided by that of a mild steel. The resistance to abrasion is measured according to ASTM Standard G 65-85 wherein an abrasive is introduced between the test specimen and a rotating wheel with a chlorobutyl rubber tire. The abrasive is a sand composed of 100% silica and of controlled size. The C content of the test specimen is 0.3 wt.% and the specimen is heat treated by quenching. The Brinell Hardness is below 500.

As shown in Figure 1, the ratio of resistance to abrasion linearly increases with the increase of the added quantity of titanium up to 0.5 wt.%.

The followings are the reason why the contents of the elements of the invented steel is specified.

C is an indispensable element in forming TiC and also enhances the hardness of the matrix of steel. However when C is increased too much, the weldability and the workability are deteriorated. Therefore the upper limit of C is determined to be 0.35 wt.%. As for the lower limit of C the minimum quantity of C wherein the effect of TiC is shown

is 0.2 wt.%.

This is the optimum range with respect to the balance of the bending workability and the weldability of the steel and the stable abrasion resistance thereof.

Si is an element effective in deoxidation process of steel making and a minimum addition of 0.1 wt.% is required for this purpose. Si is also an effective element for solution hardening. However when the Si content exceeds 1.0 wt. %, the toughness of steel is lowered and the inclusion in steel is increased. Therefore the Si content is determined to be 0.1 to 1.0 wt.%.

Mn is an element effective in quenching hardenability. At least 0.1 wt.% is required for this purpose. When the Mn content exceeds 2.0 wt.%, the weldability of steel is deteriorated. Therefore the Mn content is determined to be 0.1 to 2.0 wt.%.

In this invention Ti is one of the most important element as is C. The addition of at least 0.3 wt.% of Ti is required to stably form a large quantity of TiC. When the Ti content exceeds 1.0 wt.%, the steel possesses good abrasion resistance property but high cost is required for the production, also the weldability and the workability of steel are lowered. Therefore the Ti content is required to be 0.3 to 1.0 wt.%.

This is the optimum range with respect to the balance of the stable abrasion resistance and the economy of the steel.

In this invention, in addition to the above basic elements, at least one element selected from the group consisting of Cu, Ni, Cr, Mo and B is added to enhance the quenching hardenability and at least one element selected from the group consisting of Nb and V may be added to enhance the precipitation hardening.

Cu is an element for enhancing the quenching hardenability and effective in controlling the hardness of steel. When the Cu content is below 0.1 wt.%, the effect is not sufficient. When the Cu content exceeds 2.0 wt.%, the hot workability is lowered and the production cost is increased. Therefore the Cu content is determined to be 0.1 to 2.0 wt.%.

Ni is an element which enhances the quenching hardenability and the low temperature toughness. When the Ni content is below 0.1 wt.%, the effect is not sufficient. When the Ni content exceeds 10.0 wt.%, the production cost is increased significantly. Therefore the Ni content is determined to be 0.1 to 10.0 wt.%.

Cr is an element which enhances the quenching hardenability. When the Cr content is below 0.1 wt.%, the effect is not sufficient. When the Cr content exceeds 3.0 wt.%, the weldability is deteriorated, and the production cost is increased. Therefore the Cr content is determined to be 0.1 to 3.0 wt.%.

Mo is an element which enhances the quenching hardenability. When the Mo content is below 0.1 wt.%, the effect is not sufficient. When the Mo content exceeds 3.0 wt.%, the weldability is deteriorated, and the production cost is increased. Therefore the Mo content is determined to be 0.1 to 3.0 wt.%.

B is an element which enhances the quenching hardenability by the addition to steel even by a small amount. When the B content is below 0.0003 wt.% , the effect is not sufficient. When the B content exceeds 0.01 wt.%, the weldability is deteriorated, and the quenching hardenability is also deteriorated. Therefore the B content is determined to be 0.0003 to 0.01 wt.%.

Nb is an element effective in the precipitation hardening and can control the hardness of steel according to the purpose of steel. When the Nb content is below 0.005 wt.%, the effect is not sufficient. When the Nb content exceeds 0.5 wt.%, the weldability is deteriorated. Therefore the Nb content is determined to be 0.005 to 0.5 wt.%.

V is an element effective in the precipitation hardening and can control the hardness of steel according to the purpose of steel. When the V content is below 0.01 wt.%, the effect is not sufficient. When the V content exceeds 0.5 wt.%, the weldability is deteriorated. Therefore the V content is determined to be 0.01 to 0.5 wt.%.

In this invention no specification is required as for the method of working the steel and as for the method of heat treating of the steel. The invention may not be inoperable by heat treatments such as quenching, annealing, aging and stress relief annealing.

EXAMPLE

Table 1 shows the chemical compositions of the samples of the invented and conventional steel.

Sanples E, J, N are made of the invented steel, whereas samples marked with an asterisk are made of the steel for comparison. The chemical composition of the samples from P to R varies with respect to Ti and other alloying elements. The chemical compositions of the samples P and Q are within the same range with those of the invented steel except that of Ti. The chemical composition of the sample R is within the same range of the invented steel with respect to Ti, but out of the range with respect to C.

Table 1

Kind of Steel	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	B	N
*A	0.30	0.36	0.70	-	-	-	-	-	-	0.09	-	33

Table 1 (continued)

Kind of Steel	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	B	N
*B	0.28	0.37	0.73	-	-	-	-	-	-	0.37	-	38
*C	0.29	0.37	0.74	-	-	-	-	-	-	0.98	-	36
*D	0.29	0.36	0.71	-	-	-	-	-	-	1.41	-	30
E	0.28	0.36	0.71	0.24	0.29	-	-	-	-	0.40	-	31
*F	0.31	0.33	0.73	-	-	1.02	0.23	-	-	1.08	10	32
*G	0.19	0.33	1.44	-	-	0.27	-	-	-	0.65	9	22
*H	0.14	0.34	1.40	-	-	-	-	0.025	-	0.40	-	24
*I	0.32	0.34	0.72	-	-	-	-	-	0.045	0.41	-	21
J	0.34	0.26	1.01	0.35	0.55	-	-	0.028	0.041	0.54	-	42
*K	0.31	0.38	0.71	-	-	0.99	0.23	0.022	0.044	0.06	8	24
*L	0.29	0.38	0.70	-	-	0.99	0.23	-	0.044	0.08	9	23
*M	0.30	0.36	0.71	0.25	-	0,55	0.23	-	0,045	0.19	8	30
N	0.31	0.36	0.71	-	-	1.02	0.23	-	0.045	0.38	8	31
*O	0.31	0.33	0.73	-	0.36	0.63	0.34	-	-	1.28	-	32
*P	0.30	0.30	0.75	-	-	-	-	-	-	0.02	-	37
*Q	0.30	0.30	0.96	-	-	1.03	0.21	-	0.045	0.01	11	47
*R	0.03	0.30	0.75	-	-	-	-	-	-	0.47	-	37
Note: The values are in wt.% except B and N. The values of B and N are in ppm.												

Table 2.

	Process	Ratio of resistance to abrasion	Brinell Hardness (HB)
* A	RQ	6.5	474
*B-1	RQ	8.3	393
*B-2	RQT (400°C)	6.1	277
*C-1	DQ	9.7	335
*C-2	DQT(400°C)	6.8	245
* D	RQ	9.3	242
E	RQ	8.6	390
* F	RQ	9.1	321
* G	RQ	4.7	302
* H	DQ	3.4	253
* I	RQ	10.1	451
J	DQ	8.9	417
* K	RQ	6.4	503
*L-1	AR	4.5	293
*L-2	DQ	8.2	507
*M-1	AR	4.7	286
*M-2	DQ	9.1	454
N-1	AR	6.1	274
N-2	RQ	11.6	448
*O-1	AR	7.3	246

Table 2. (continued)

	Process	Ratio of resistance to abrasion	Brinell Hardness (HB)
*O-2	RQ	11.1	275
* P	RQ	4.9	464
*Q-1	AR	2.8	326
*Q-2	RQ	5.2	481
* R	RQ	1.2	122

Table 2 shows the process of making the samples, the ratio of the resistance to abrasion and the Brinell Hardness of the samples. Samples B, C, E, I, J, N are made of the invented steel, whereas samples marked with an asterisk are made of the steel for comparison.

The abrasion test is carried out according to ASTM G 65-85 as described before. The measurement of the abrasion is done by the change of the weight of the sample.

As described before the ratio of resistance to abrasion is the ratio of the weight change of the specimen made of the invented steel versus that of the specimen made of a mild steel.

The processes in the table are classified as follows ; AR, as rolled; RQ, as quenched after heated to 900 °C following the rolling and air-cooling; RQT, as tempered at the temperature shown in the parenthesis after RQ treatment; DQ, as directly quenched after finish rolled at 880 °C following the heating of the slab at 1150 °C; DQT, as tempered at the temperature shown in the parenthesis following DQ. The thickness of the sample is 15 mm. The kind of steel in Table 1 corresponds with those in Table 2.

The steel for comparison P corresponds with the invented steel B-1 except that the Ti content is below the range of the invented steel. Examining the ratio of the resistance to abrasion, it is found that the ratio is 4.9 in the steel for comparison P, whereas the ratio of the invented steel B-1 is 8.3.

This is to say that the ratio of the invented steel can be enhanced twice as much as that of the steel for comparison which is a conventional abrasion resistant steel. Moreover the hardness of the invented steel is lower than those of the steel for comparison.

This result agrees with the purpose of the invention wherein the invented steel possesses high resistance to abrasion and low hardness.

The steel for comparison Q corresponds with the invented steel N. The ratios of the resistance to abrasion in N are higher than that of Q.

The steel for comparison R corresponds with the invented steel B-1. The C content of the steel for comparison R is below the range of the invented steel. Since the C content of the steel R is so low that the ratio of the resistance to abrasion is significantly lower than that of B-1.

Claims

1. An abrasion resistant steel comprising the following constituents in proportions by weight:

C 0.2 to 0.35 %
Si 0.1 to 1.0 %
Mn 0.1 to 2.0 %
Ti 0.3 to 1.0 %

and one or more quench hardening constituents from the group consisting of copper, nickel, chromium, molybdenum and boron in the following proportions by weight:

Cu 0.1 to 2.0 %
Ni 0.1 to 10.0 %
Cr 0.1 to 3.0 %
Mo 0.1 to 3.0 %
B 0.0003 to 0.01 %

and optionally comprising one or more precipitation hardening constituents from the group consisting of niobium

and vanadium in the following proportions by weight:

Nb 0.005 to 0.5 %
V 0.01 to 0.5 %

wherein the balance is Fe plus incidental impurities, if any.

2. An abrasion resistant steel as claimed in claim 1 further characterised in that the quench hardening constituent is boron in the following proportions by weight:

B 0.0003 to 0.01 %.

3. An abrasion resistant steel as claimed in claim 1 further characterised in that the quench hardening constituent is copper in the following proportions by weight:

Cu 0.1 to 2.0 %.

4. An abrasion resistant steel as claimed in claim 1 further characterised in that the quench hardening constituent is nickel in the following proportions by weight:

Ni 0.1 to 10.0 %.

5. An abrasion resistant steel as claimed in claim 1 further characterised in that the quench hardening constituent is chromium in the following proportions by weight:

Cr 0.1 to 3.0 %.

6. An abrasion resistant steel as claimed in claim 1 further characterised in that the quench hardening constituent is molybdenum in the following proportions by weight:

Mo 0.1 to 3.0 %.

Patentansprüche

1. Abriebfester Stahl, der die folgenden Bestandteile in den folgenden Gewichtsproportionen

C 0,2 bis 0,35%
Si 0,1 bis 1,0%
Mn 0,1 bis 2,0%
Ti 0,3 bis 1,0%

und einen oder mehrere Bestandteile zum Abschreckhärten aus der aus Kupfer, Nickel, Chrom, Molybdän und Bor bestehenden Gruppe in den folgenden Gewichtsproportionen

Cu 0,1 bis 2,0%
Ni 0,1 bis 10,0%
Cr 0,1 bis 3,0%
Mo 0,1 bis 3,0%
B 0,0003 bis 0,01%

enthält, und der wahlweise einen oder mehrere Bestandteile zum Ausscheidungshärten aus der aus Niob und Vanadium bestehenden Gruppe in den folgenden Gewichtsproportionen enthält:

Nb 0,005 bis 0,5%
V 0,01 bis 0,5%

wobei der Ausgleich Eisen und Begleitverunreinigungen, wenn irgendwelche vorhanden sind, sind.

2. Abriebfester Stahl nach Anspruch 1, der außerdem dadurch gekennzeichnet ist, daß der Bestandteil zum Abschreckhärten Bor in den folgenden Gewichtsproportionen ist:

   B 0,0003 bis 0,01%.

3. Abriebfester Stahl nach Anspruch 1, der außerdem dadurch gekennzeichnet ist, daß der Bestandteil zum Abschreckhärten Kupfer in den folgenden Gewichtsproportionen ist:

   Cu 0,1 bis 2,0%.

4. Abriebfester Stahl nach Anspruch 1, der außerdem dadurch gekennzeichnet ist, daß der Bestandteil zum Abschreckhärten Nickel in den folgenden Gewichtsproportionen ist:

   Ni 0,1 bis 10,0%.

5. Abriebfester Stahl nach Anspruch 1, der außerdem dadurch gekennzeichnet ist, daß der Bestandteil zum Abschreckhärten Chrom in den folgenden Gewichtsproportionen ist:

   Cr 0,1 bis 3,0%.

6. Abriebfester Stahl nach Anspruch 1, der außerdem dadurch gekennzeichnet ist, daß der Bestandteil zum Abschreckhärten Molybdän in den folgenden Gewichtsproportionen ist:

   Mo 0,1 bis 3,0%.

Revendications

1. Acier résistant à l'abrasion comprenant les constituants suivants en proportions en poids:

   C 0,2 à 0,35%
   Si 0,1 à 1,0%
   Mn 0,1 à 2,0%
   Ti 0,3 à 1,0%

   et un ou plusieurs constituants de durcissement par trempe parmi le groupe constitué du cuivre, du nickel, du chrome, de molybdène et du bore dans les proportions en poids suivantes:

   Cu 0,1 à 2,0%
   Ni 0,1 à 10,0%
   Cr 0,1 à 3,0%
   Mo 0,1 à 3,0%
   B 0,0003 à 0,01%

   et comprenant éventuellement un ou plusieurs constituants de durcissement par précipitation parmi le groupe constitué du niobium et du vanadium dans les proportions en poids suivantes:

   Nb 0,005 à 0,5%
   V 0,01 à 0,5%

   dans lequel le reste est Fe plus des impuretés accidentelles, s'il en exite.

2. Acier résistant à l'abrasion selon la revendication 1, caractérisé en outre en ce que le constituant de durcissement par trempe est le bore dans les proportions en poids suivantes:

   B 0,0003 à 0,01%.

3. Acier résistant à l'abrasion selon la revendication 1, caractérisé en outre en ce que le constituant de durcissement

par trempe est le cuivre dans les proportions en poids suivantes:

Cu 0,1 à 2,0%.

4. Acier résistant à l'abrasion selon la revendication 1, caractérisé en outre en ce que le constituant de durcissement par trempe est le nickel dans les proportions en poids suivantes:

Ni 0,1 à 10,0%.

5. Acier résistant à l'abrasion selon la revendication 1, caractérisé en outre en ce que le constituant de durcissement par trempe est le chrome dans les proportions en poids suivantes:

Cr 0,1 à 3,0%.

6. Acier résistant à l'abrasion selon la revendication 1, caractérisé en outre en ce que le constituant de durcissement par trempe est le molybdène dans les proportions en poids suivantes:

Mo 0,1 à 3,0%.

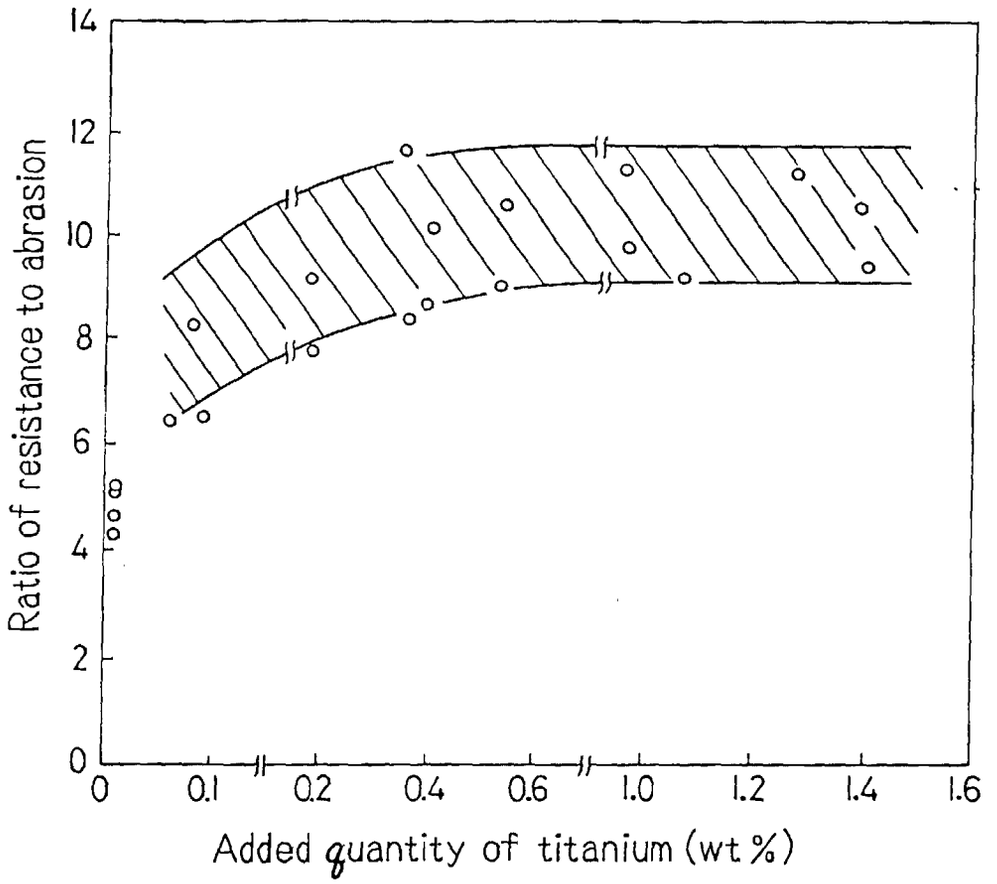
14
12
10
8
6
4
2
0
Ratio of resistance to abrasion
0
0.1
0.2
0.4
0.6
1.0
1.2
1.4
1.6
Added quantity of titanium (wt %)

Fig. 1