FIG. 1

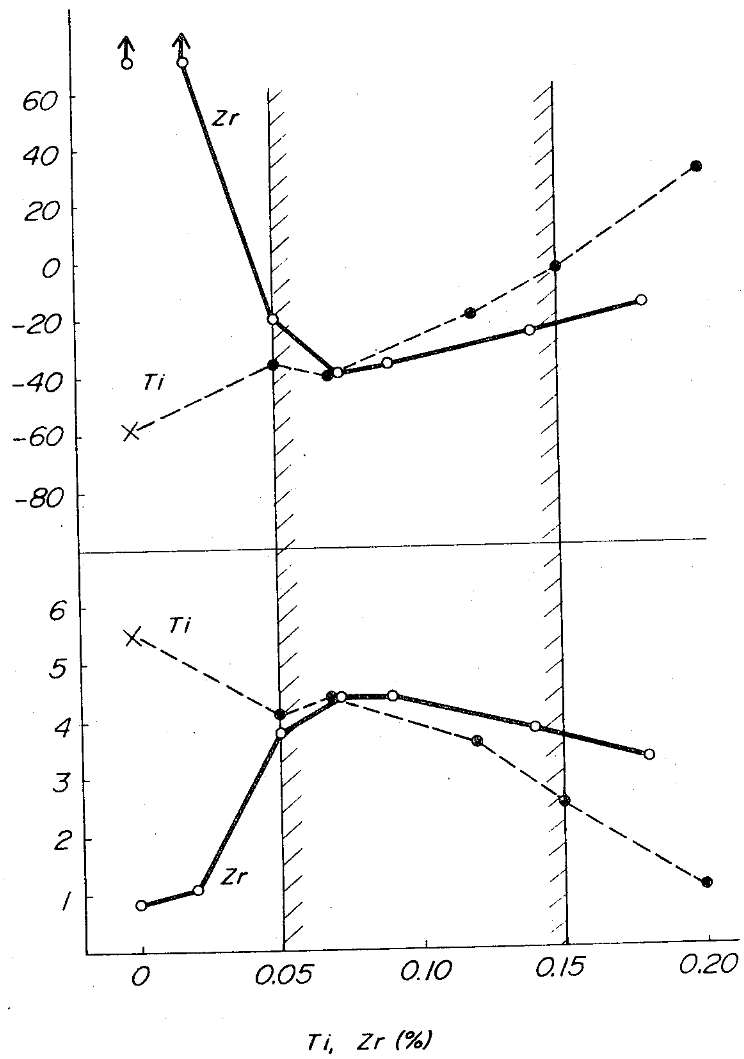


FIG. 2

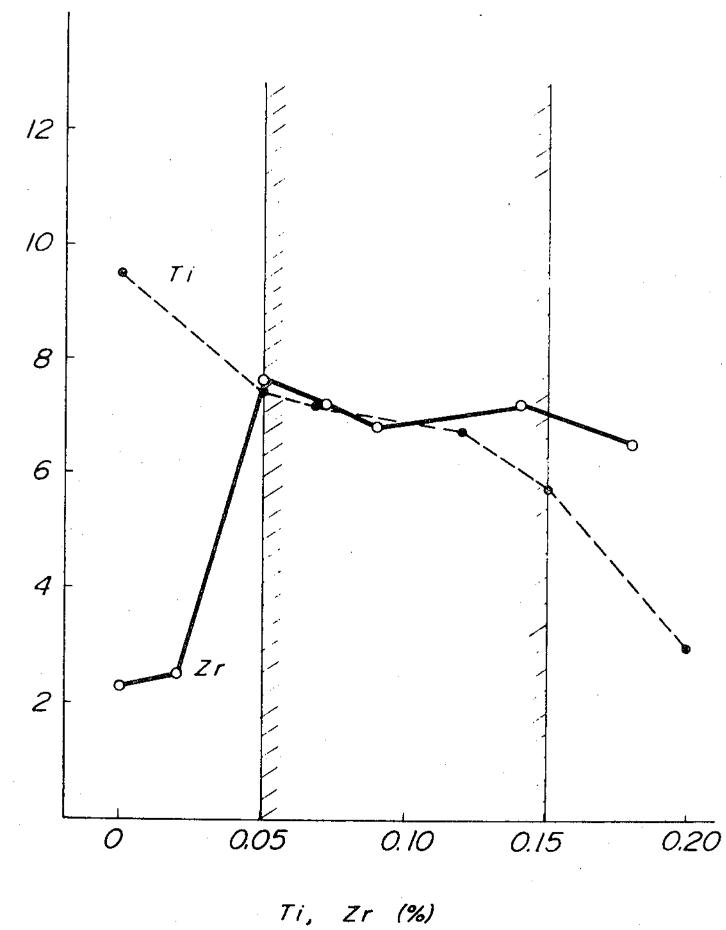
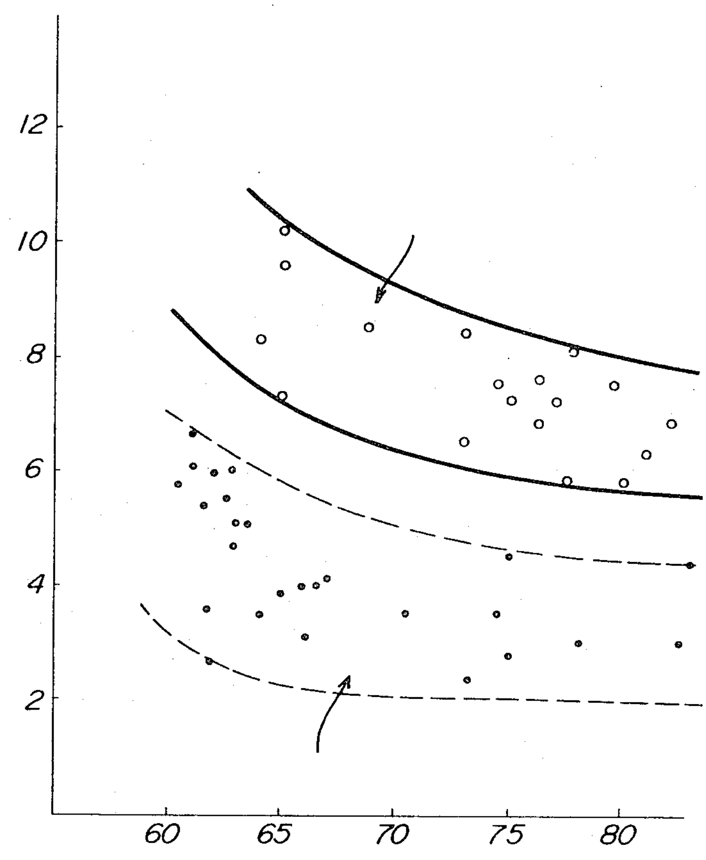


FIG. 3



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NONTHERMAL REFINING TYPE HIGH TENSION STEEL EXHIBITING EXCELLENT COLD-WORKABILITY

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U.S. Cl. 75—123 4 Claims

ABSTRACT OF THE DISCLOSURE

A nonthermal refining type high tension steel substantially consisting of 0.05 to 0.15% C and complex addition of 0.01 to 0.10% Nb, 0.03 to 0.15% Ti and 0.05 to 0.15% Zr, unavoidable impurities and remainder Fe, exhibits high tensile strength of more than 60 kg./mm.^{2} or yield stress of more than 45 kg./mm.^{2} and excellent cold-workability.

BACKGROUND OF INVENTION

This invention relates to a novel nonthermal refining type high tension steel exhibiting excellent cold-workability, and more particularly such steel having high tensile strength or yield stress and exhibiting excellent cold-workability.

A high tension steel having tensile strength of 60 kg./mm.^{2}, 70 kg./mm.^{2}, or 80 kg./mm.^{2} has already been developed and used. A number of steels has been developed which aims to improve cold-workability. However, no steel has been developed which exhibits both excellent cold-workability simultaneously with high tensile strength of 70 kg./mm.^{2} or 80 kg./mm.^{2} grade.

If a steel were developed exhibiting both high strength and excellent workability, it could be used in numerous instances, such as for use as a beam of a crane, a frame of autotrucks, a container material or a structural material for autos and other vehicles, etc. These uses require such properties as high strength, good cold-workability, good flatness, good weldability, high impact value and low cost.

For the purpose of satisfying the above requirements, known quenching and tempering treatments have usually been carried out to attain high tensile strength of 60 kg./mm.^{2}, 70 kg./mm.^{2}, or 80 kg./mm.^{2} grades. However, such steel generally tends to become worse in cold-workability and flatness of surface in spite of improved workability of welding and impact strength. Also, disadvantageously, the cost is higher. Such tendency increases as the thickness increases. Thus, these steels are unsuitable for the above-mentioned purposes and uses. It is generally well known that cold-workability becomes worse as strength increases. In the prior art, there is no steel which exhibits excellent cold-workability and high strength and is available at low cost.

SUMMARY OF INVENTION

Faced with the foregoing state of the art, the inventors carried out studies to improve weldability, impact strength and other properties and lower cost.

Accordingly, this inventive steel has been developed to

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solve the above mentioned problems and eliminate the deficiencies of the prior art.

This invention encompasses a low C-Nb-Ti-Zr system composition. The chemical composition of this inventive steel substantially consists of, as the inventive portion thereof, 0.05 to 0.15% (by weight, the same holding herein) C and coexistence of 0.01 to 0.10% Nb, 0.03 to 0.15% Ti and 0.05 to 0.15% Zr. As other elements, 0.10 to 1.00% Si, 0.80 to 1.80% Mn and 0.01 to 0.10 sol. Al are included in steel. One or more elements selected from the group consisting of 0.10 to 0.50% Cr, 0.10 to 0.50% Cu, 0.10 to 0.50% Mo, 0.03 to 0.20% V and 0.10 to 0.50% Ni can be further added. Unavoidable impurities may be present and the remainder is Fe. The inventive steel may be as rolled without any thermal refining treatment, and advantageously, has the excellent mechanical properties of high strength, good weldability, good cold-workability, good flatness, high impact strength, and low cost.

An object of the invention is to provide a non-thermal refining type high tension steel exhibiting excellent cold-workability simultaneously with high tensile strength.

Another object of this invention is to provide a non-thermal refining type high tension steel exhibiting good flatness of surface, good weldability and high impact value as well as excellent cold-workability and high strength as rolled without thermal treatments.

BRIEF DESCRIPTION OF DRAWING

FIG. 1 depicts a graph showing change of impact properties with content of Ti or Zr;

FIG. 2 depicts a graph showing the relationship between content of Ti or Zr and notch elongation; and

FIG. 3 depicts a graph showing the relationship between tensile strength and notch elongation.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The general effects of adding Nb, Ti or Zr to steel is qualitively known. Steels including Nb, Ti or Zr have been developed and used. For example, a typical steel is reported in Stahl and Eisen, 90 (1970), Heft 22, S. 1255 to 1262 as Nb-Zr system steel or in Thyssenforschung, 2 (1970), Heft 3, S. 86 to 95 as Ti-Nb system steel. However, when the above reports are examined in detail, it is found that the effects are far from the objects of this invention.

On the other hand, substantial coexistence of C, Nb, Ti and Zr in steel is an essential requirement of this invention. If any of these elements is lacking, the resulting steel cannot exhibit the desired properties, when rolled without any thermal refining treatment.

This invention encompasses steels having the following composition: C, 0.05 to 0.15%; Mn, 0.80 to 1.80%; Ti, 0.03 to 0.15%; sol. Al, 0.010 to 0.100%; Si, 0.10 to 1.00%; Nb, 0.01 to 0.10%; Zr, 0.05 to 0.15%; unavoidable impurities and remainder iron.

The above composition is preferred embodiment. When necessary, one or more elements selected from the following group of elements may be further added: Cr, 0.10 to 0.50%; Mo, 0.10 to 0.50%; Ni, 0.10 to 0.50%; Cu, 0.10 to 0.50% and V, 0.03 to 0.20%. By such addition, the mechanical properties are further improved, and it is possible to obtain desirable properties for relatively large thicknesses.

The reasons, which are fully documented in the following data, that content of each of the elements is limited as aforementioned are as follows:

Less than 0.05% C does not give the required strength to steel and more than 0.15% C makes cold-workability worse.

Si plays a part in controlling strength in addition to producing a deoxidizing effect. However, when Si content is more than 1.00%, toughness of steel becomes worse.

In the case of less than 0.80% Mn, the required strength is impossible to be obtained and when it is more than 1.80%, the formed crystal structure becomes unstable and toughness becomes worse.

Nb is added to obtain the desired strength. However, in case of less than 0.01%, the desired strength is impossible to be imparted to the steel and even if the Nb content is more than 1.80%, the adding effect is saturated and consequently any greater percentage of Nb becomes meaningless.

Ti is added to improve the strength and simultaneously therewith to play a part in adjusting formation of sulfide in steel. The adding of less than 0.03% Ti shows little effect and the adding of more than 0.15% Ti rapidly makes the cold-workability and impact properties worse.

Zr is added to mainly control the forming of sulfide and improve cold-workability and impact properties. However, in the case of less than 0.30% Zr, there is very little improvement of cold-workability and in the case of more than 0.15% Zr, conversely the impact properties become worse, while the cold-workability is kept for the most part as it is.

Sol. Al is necessary to deoxidize and obtain good yield of added Ti and Zr. Such effects are impossible to be obtained in the case of less than 0.010% Sol. Al. More than 0.10% sol. Al makes fluidity and cleanliness of the batch in furnace.

In this invention, one or more among the group of elements comprising Cr, Cu, Mo, V and Ni may be further added to the above preferred composition, if necessary or desired in order to obtain a desired level of strength. In such case, when content of each of Cr, Cu, Mo, Ni is less than 0.10% or that of V, less than 0.03%, the desired strength is not obtained. When the content of said Cr, Cu, Mo and Ni is more than 0.50% or that of V, more than 0.20%, a disproportionate little effect is obtained for rise in cost.

S content is not limited in this invention. However, it has been confirmed that less than 0.01% S is very effective for improving cold-workability. When tensile strength of more than 70 kg./mm.[2] is desired, the S content is a suitable means for obtaining same.

As mentioned above, the substantial coexistence of Nb, Ti and Zr is one of the esential requirements. When one of the elements is not added, the required mechanical properties cannot be imparted to steel as rolled and without any thermal refining treatment. The properties are based on geometrical action of the three elements. The adding effect of Ti or Zr among the three elements is shown in FIGS. 1 and 2. Both FIGS. 1 and 2 show the further adding effects of Ti to Nb+Zr, including within the range of the aforementioned amounts. Similarly, the further adding effects of Zr, to Nb+Ti are shown in FIGS. 1 and 2.

Referring to FIG. 1, it will be understood that the composition of elements specified in this invention is very effective and the most suitable. When Ti content is more than 0.15%, both the fracture transition temperature and absorption energy at 0° C., which is measured in the transverse direction to rolling, become substantially worse. When Zr content is less than 0.05%, the fracture transition temperature is very high and the absorption energy is not improved. When Zr content is more than 0.15%, the absorption energy level becomes lower with the same tendency as shown in the case of less than 0.05%.

In FIG. 2, changes of notch elongation, which substantially corresponds to cold-workability, depending upon Ti or Zr content are shown. The relationship of Nb, Ti and Zr content is in the same manner as that of FIG. 1. When Ti content is more than 0.15%, the notch elongation rapidly becomes lower. When it is less than 0.05%, the notch elongation becomes substantially worse. When the Ti content is about 0.05%, the notch elongation is improved and shows little change even if the content is increased.

FIG. 3 shows the relationship between tensile strength and notch elongation. Accordingly to the relationship shown in FIG. 3, it is apparent that this inventive steel is far superior to the prior art steels.

The actual examples based on this invention are as follows. Such examples are shown in comparison with prior art steels.

Manufacturing conditions:

Chemical composition—As shown in Table 1

Steel making stage—

Employed furnace—basic oxygen furnace, 85 ton

After ordinary deoxidizing operation, kind of alloy—Fe-Nb; Fe-Ti and Fe-Zr or Si-Zr

Hot rolling stage followed by ordinary casting and slabbing.

Empolyed rolling mill—Tandem Hot Rolling Mill

Hot rolling requirements—ordinary

TABLE I

	C	Si	Mn	P	S	Nb	Ti	Zr	Sol·Al	Others	C. eq.[2]
A[1]	0.09	0.26	1.03	0.014	0.018	0.027	0.13	----------	0.052	----------	0.27
B[1]	0.18	0.20	1.10	0.013	0.008	----------	0.10	0.10	0.038	----------	0.37
C[1]	0.10	0.21	1.25	0.016	0.010	0.009	0.18	0.08	0.025	----------	0.32
D[1]	0.18	0.23	1.27	0.011	0.008	0.035	0.08	0.07	0.038	----------	0.40
E	0.12	0.26	0.85	0.013	0.020	0.010	0.09	0.10	0.023	----------	0.27
F	0.09	0.32	1.24	0.015	0.017	0.035	0.08	0.06	0.052	----------	0.31
G	0.11	0.32	1.26	0.016	0.008	0.035	0.12	0.07	0.064	----------	0.33
H	0.10	0.28	1.22	0.016	0.006	0.040	0.06	0.08	0.082	----------	0.31
I	0.13	0.27	1.15	0.021	0.017	0.023	0.08	0.07	0.066	----------	0.33
J	0.09	0.52	1.35	0.012	0.006	0.043	0.08	0.11	0.042	----------	0.33
K	0.11	0.48	1.30	0.010	0.004	0.038	0.10	0.13	0.029	Mo, 0.22	0.40
L	0.10	0.63	1.40	0.015	0.008	0.032	0.06	0.07	0.030	Cr, 0.21 Cu, 0.28	0.40
M	0.08	0.50	1.68	0.018	0.005	0.046	0.08	0.12	0.042	Mo, 0.15 Cu, 0.20 V, 0.08	0.42
N	0.10	0.38	1.22	0.015	0.010	0.030	0.06	0.08	0.038	Ni, 0.23 Cu, 0.25	0.33

[1] Steels A to D are comparative steels. Steels E to N are this invention steels.
[2] C.eq.=C+ (1/6)Mn+ (1/24) Si+(1/40)Ni+ (1/5)Cr+ (1/4)Mo+ (1/14)V.

TABLE II

Steel	Thickness (mm.)	Coiling temperature (° C.)	Tensile properties: Yield stress (kg./mm.²)	Tensile properties: Tensile strength (kg./mm.²)	Cold bending workability: Bending 180° (0.5 t.)	Cold bending workability: Notch elongation (percent)	Impact properties[1]: Fracture transition temperature (° C.)	Impact properties[1]: Absorption energy at 0° C., (kg.-m.)
A	6.0	610	58.7	66.6	Crack	2.3	+100	0.3
B	6.0	640	52.4	61.8	do	3.2	+40	0.8
C	6.0	590	64.2	74.5	do	3.5	+30	1.1
D	6.0	510	75.7	82.9	do	4.4	−10	2.2
E	6.0	525	58.6	65.5	Good	10.2	−70	4.4
F	6.0	530	71.3	80.1	do	5.7	−7	2.2
G	6.0	520	73.4	81.3	do	6.3	−20	3.0
H	8.0	560	64.4	73.0	do	8.4	−38	4.0
I	8.0	590	59.4	65.4	do	7.3	−32	3.5
J	8.0	590	68.3	75.4	do	7.2	−30	4.3
K	8.0	540	72.8	82.5	Microfissure	6.8	−18	3.1
L	10.0	590	62.3	72.8	do	8.7	−35	4.0
M	10.0	540	72.5	81.6	do	6.9	−28	3.8
N	10.0	560	59.9	65.8	do	8.9	−65	4.5

[1] Sharp test piece: 5 mm. x 10 mm. x 55 mm.

NOTE.—Finishing thickness, 6.0 mm, to 10.0 mm.; Coiling requirements, ordinary.

The mechanical properties of the above steels are shown in Table II.

According to Table I and Table II, it will be apparent that each of the strength (i.e. tensile strength and yield strength), the cold-workability (i.e. bending property and notch elongation) and the impact properties (i.e. fracture transition temperature and absorption energy) is far superior to that of the prior comparative steels. Tensile strength is in the 60 kg./mm.², 70 kg./mm.², or 80 kg./mm.² grades and yield stress is above 45 kg./mm.² with relative ease and shows 60 kg./mm.² and 75 kg./mm.² range. Cold-workability is excellent. The carbon equivalent (C eq.) shown in Table I is low and shows good weldability. Simultaneously, it is also understood that the strength of steels including less than 0.01% S is superior to that of other steels. Moreover, production cost is low because among other reasons, the steel may be used as only rolled. There is no need for any thermal treatments. The strength may be further improved by adding one or more elements such as Cr, Cu, Mo, V or Ni.

The foregoing description is only illustrative of the principles of this invention. Numerous variations and modifications thereof would be apparent to one skilled in the art. All such variations and modifications are to be considered to be within the spirit and scope of the invention.

What is claimed is:

1. Nonthermal refining type high tension steel exhibiting excellent cold-workability and tensile strength of at least 60 kg./mm.² consisting essentially of at least 0.05 to 0.15% C; 0.01 to 0.10% Nb; 0.03 to 0.15% Ti; 0.05 to 0.15% Zr, unavoidable impurities and remainder Fe.

2. Composition of claim **1**, further comprising 0.10 to 1.00% Si; 0.80 to 1.80% Mn and 0.01 to 0.10% sol. Al.

3. Composition of claim **2**, further comprising one or more of the elements selected from the group consisting of 0.10 to 0.50% Cr; 0.10 to 0.50% Cu; 0.10 to 0.50% Mo; 0.03 to 0.20% V and 0.10 to 0.50% Ni.

4. Composition of claim **3**, further comprising S in an amount less than 0.010%.

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