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HIGH TENSION TOUGH STEEL HAVING EXCELLENT PROPERTY RESISTING TO DELAYED RUPTURE

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4 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a high tension tough steel having excellent property resisting to delayed rupture, consisting of 0.05 to 0.80% C, 0.05 to 2.00% Si, 0.30 to 2.00% Mn, 0.05 to 6.00% Cr 0.01 to 0.30% Tr, 0.005 to 0.30% Zr, 0.5 to 0.008% B as basis elements at least one element selected from the group consisting of Sn, Sb and As, from the group consisting of Nb+Ta, W, Hf and Pd and further from the group consisting of Mo, Ni, V and Cu, balance being Fe and impurities

This invention relates to a high tension tough steel having an excellent property resisting to delayed rupture and a tensile strength of above 100 kg./mm.

Though in recent years the strength of high tension steels is attaining a higher level than ever, there occur troubles on account of delayed rupture, that is, a phenomenon that a brittle rupture suddenly occurs after the lapse of a certain time, while the steel is during the use in the state of given load stress under natural circumstances. This phenomenon is said to be particularly remarkable in the case of a high tension steel having a tensile strength of more than 130 kg./mm.². Hydrogen embrittlement, corrosion or static fatigue is said to be the cause of this phenomenon of delayed rupture, and the degree thereof varies with various conditions such as circumstances of application, shape of parts of construction and the presence of heat treatment and the like. However, the cause of delayed rupture should be considered essentially in connection with characteristics of the steel materials.

The object of the present invention is to provide a low alloy high tension steel having strong resistance to delayed rupture and a tensile strength of above 100 kg./mm.², particularly to provide a steel material which can display a delayed rupture resistance far superior to any conventional steel material at such a high level of tensile strength as more than 130–140 kg./mm.².

The steel of the present invention has the following chemical composition: that is, it is composed of 0.05 to 0.80 wt. percent C, 0.05 to 2.00 wt. percent Si, 0.30 to 2.00 wt. percent Mn, 0.05 to 6.00 wt. percent Cr, 0.01 to 0.30 wt. percent Ti, 0.005 to 0.30 wt. percent Zr, and 0.0005 to 0.008 wt. percent B as basic alloying elements and further at least one element selected from the group consisting of Sn, Sb and As in an amount of 0.03 to 0.50 wt. percent. However, the object of the present invention can be better achieved, if there is further added to the steel having the above mentioned composition at least one element selected from the group consisting of Nb+Ta, W, Hf and Pd in an amount of less than 1.00 wt. percent in the case of Nb+Ta, less than 1.00 wt. percent in the case of W, less than 0.50 wt. percent in the case of Hf and less than 1.00 wt. percent in the case of Pd. For the purpose of improving mechanical properties and hardenability of the steel of the present invention, however, at least one element selected from the group consisting of Mo, Ni, V and Cu may be added to each of

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the above mentioned two kinds of steels of the present invention respectively in an amount of 0.05 to 1.00 wt. percent Mo, 0.05 to 5.00 wt. percent Ni, 0.005 to 1.00 wt. percent V and 0.03 to 0.50 wt. percent Cu.

The steel of the present invention is characterized in that by causing conventional steel materials of various kinds such as Cr steel, Cr-Mo steel, Cr-Mo-Ni steel, Si-Mn steel, Si-Mn-Cr steel and the like, which have been made high tension steels having a tensile strength of more than 100 kg./mm.² by heat treatment and/or cold working, to contain Ti, Zr and B and further at least an element selected from the group consisting of Sn, Sb and As such an excellent property resisting to delayed rupture as can not easily be expected from a sole effect of each element added can be obtained, and still further by adding to the said steel materials having the above mentioned composition at least one element selected from the consisting of Nb+Ta, W, Hf and Pd in the range specified for each element the delayed rupture resisting property obtained by the above mentioned steel materials are all the more improved that such an excellent property resisting to delayed rupture as never attained with any conventional steel material can be obtained.

The reasons why the content of each constituent of the steel of the present invention has been specified as above mentioned shall be explained in the following.

C is added to a steel to impart the strength and hardenability required for the steel, but if the content of C exceeds 0.80 wt. percent, an improvement in the hardenability can no more be expected and there is further danger of the toughness being extremely reduced by the formation of free cementite. Therefore, the upper limit of C was specified as 0.80 wt. percent. On the other hand, if the content of C is too small, the formation of martensite at the time of heat treatment becomes difficult, and a sufficient strength can not be obtained even by subjecting the steel to a cold working. Therefore, the lower limit was specified as 0.05 wt. percent.

Si and Mn are elements necessary for deoxidation in the steel manufacturing process, but moreover effective for improving the hardenability and bettering the strength and toughness. However, if the content of each element is above 2.00 wt. percent, the effect of bettering the strength and toughness will be weakened and the steel manufacturing operation will be difficult. Therefore, the upper limit for both elements was made 2.00 wt. percent respectively. On the other hand, as the addition of Si at least in an amount of 0.05 wt. percent is necessary for deoxidation in the steel manufacturing process, the lower limit of Si was specified as 0.05 wt. percent. The addition of Mn was determined as more than 0.30 wt. percent, because the effect of Mn of improving the hardenability will be diminished and also the effect of preventing damage caused by S during a hot working will be weakened, if the content of Mn is too small.

Cr is also added to improving the hardenability, strength and toughness of the steel. However, when the addition exceeds 6.0 wt. percent, the effect can not be obtained in proportion to the addition, while no effect can be obtained, if the addition is below 0.05 wt. percent.

Ti, Zr, B, Sn, Sb and As are very elements, to which the marked improvement in the property resisting to delayed rupture of the steel of the present invention are attributed. By multiplex effects resulted from combining Ti, Zr, B and at least one element selected from the group consisting of Sn, Sb and As in proper amounts such an excellent effect as can not easily be expected from sole effect of each of these elements can be displayed. However, as it was confirmed by the experiments that the addition of each of these elements exceeds a certain limit,

for instance 0.03 wt. percent for Ti and Zr respectively, 0.008 wt. percent for B and 0.50 wt. percent for at least one element selected from the group consisting of Sn, Sb and As, not only said effect to be obtained by these elements will be lost, but also unfavorable phenomena will appear in the aspects of the toughness and the workability, the upper limit for each element was restricted to the above mentioned value respectively. Likewise, the lower limit for each of these elements was specified as 0.01 wt. percent for Ti, 0.005 wt. percent for Zr, 0.0005 wt. percent for B and 0.03 wt. percent for at least one element selected from the group, consisting of Sn, Sb and As, because the amount of less than the above mentioned value will produce no effect.

Thus, by specifying the composition of the steel of the present invention as above mentioned, it was proved to be able to impart to the steel not only a high tensile strength as of more than 100 kg./mm.², but also the de-

sired property resisting to delayed rupture. However, it was further discovered by the inventors that Nb+Ta, W, Hf and Pd were also elements effective for improving the delayed rupture resisting property, and it was succeeded to obtain a steel having excellent delayed rupture resisting property by adding these elements in the ranges as specified by the present invention. The upper limits were restricted to 1.0 wt. percent for Nb+Ta, 1.00 wt. percent for W, 0.5 wt. percent for Hf and 1.00 wt. percent for Pd. These limits were also of the economic nature, because more than these limits could not result in effect in proportion to the additions. As any addition of these elements below the above mentioned limits could bring corresponding effects, the lower limits for these elements were not especially specified. Also in this case, the excellent effect obtained by adding at least one element selected from these elements was attributable to multiplex effects of these elements with other elements already added.

It is to note that even with the present industrial refining technique it is still impossible to completely separate Nb and Ta, consequently Nb can be obtained only in the state of being accompanied with Ta. Therefore, in the present application Nb and Ta are expressed as Nb+Ta. However, if a cheap separation of Nb and Ta on an industrial scale may be realized, the sole addition of both elements will be possible.

Examples of the present invention shall be explained in the following. Table shows a comparison of the delayed rupture resisting property of the steels of the present invention with that of conventional steel materials. The delayed rupture test adopted in the present invention was carried out by subjecting various notched test pieces to a tensile stress corresponding to 90% of a notch tensile strength in an atmosphere of high humidity.

	C	Si	Mn	Cr	Ti	Zr	B	Sn	Sb	As	Others	Mo	Ni	V	Cu	Tensile strength, kg./mm. ²	Lapse of time up to delayed rupture (hr.)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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Remarks: The time up to the occurrence of delayed rupture is measured and indicated as hours taken until the complete rupture of a test piece provided with a notched groove occurs, said test piece being laid in the space part of a water tank in which water having a temperature of 40°C is stored under the state of said test piece being subjected to a tensile stress. This test means so-called rupture-promoting test in an atmosphere of high humidity. A mark of X indicates a rupture.

As compared with samples of conventional steel materials B1 to B11, among which some samples contain only one of element selected from the group consisting of Ti, Zr and B, but other samples contain none of them, all the samples of the present invention A1 to A18 contain three of elements Ti, Zr and B in addition C, Si and Cr as the basic constituents. However, the reference B1, B2, B7 which contain one of the above mentioned three elements show that by adding only one of these three elements the effect of preventing delayed rupture cannot be obtained.

On the contrary, A1, A2, A3, A13 and A14 of the present invention show that by the addition of at least one element selected from the group consisting of Sn, Sb and As the time up to the occurrence of delayed rupture can be prolonged by a large margin. Also for instance, the comparison of A4 with B4, or A5 to B5 demonstrates clearly the effect obtained by adding the elements selected from the group of Sn, Sb and As. Further, the samples A6, A7, A8, A11, A14, A15 and A18 show that by adding further at least one element selected from the group consisting of Nb+Ta, W, Hf and Pd the property resisting to delayed rupture can be all the more improved, which is particularly distinguished when comparing with the reference samples B4, B5, B6, B7, B9, B10 and B11 which contain at least one element selected from the group consisting of Mo, Ni, V. In general, Ni, Mo, Cu and V are known as elements which are also effective for improving the strength, toughness or hardenability of steels. Even when the steel of the present invention contains these elements, however, it does not mean that the object of the present invention might be lost thereby. If these elements are to be added to the steel of the present invention, at least one element selected from this group is preferable to be added in the following ranges: 0.05 to 5.00 wt. percent Ni, 0.05 to 1.00 wt. percent Mo, 0.005 to 1.00 wt. percent V and 0.03 to 0.50 wt. percent Cu. If more than these ranges, the corresponding effects can not be expected, but less than these, no effect can be obtained.

On account of an excellent property resisting to delaying rupture owing to its chemical composition as above mentioned, the steel of the present invention is particularly fit for use in the field where the phenomenon of delayed rupture raises a grave technical issue, for instance, for use as high tensile strength bolts, steel wires or bar steels for prestressed concrete or other structure steel materials or parts thereof, in which an extreme high tensile strength is required.

Having thus described the invention, what is claimed is:

1. A high tension tough steel having excellent delayed rupture resisting properties, consisting of 0.05 to 0.80 wt. percent C, 0.05 to 2.00 wt. percent Si, 0.30 to 2.00 wt. percent Mn, 0.05 to 6.00 wt. percent Cr, 0.01 to 0.30 wt. percent Ti, 0.005 to 0.30 wt. percent Zr and 0.0005 to 0.008 wt. percent B as basic elements and further at least one element selected from the group consisting of Sn, Sb and As in the range of 0.03 to 0.5 wt. percent and the balance being Fe and unavoidable impurities.

2. A high tension tough steel having excellent delayed rupture resisting properties, consisting of 0.05 to 0.80

wt. percent C, 0.05 to 2.00 wt. percent Si, 0.30 to 2.00 wt. percent Mn, 0.05 to 6.00 wt. percent Cr, 0.01 to 0.30 wt. percent Ti, 0.005 to 0.30 wt. percent Zr and 0.0005 to 0.008 wt. percent B as basic elements, at least one element selected from the group consisting of Sn, Sb and As in the range of 0.03 to 0.50 wt. percent and further at least one element selected from the group consisting of Nb+Ta in an amount up to 1.00 wt. percent, W in an amount up to 1.00 wt. percent, Hf in an amount up to 0.50 wt. percent and Pd in an amount up to 1.00 wt. percent, the balance being Fe and unavoidable impurities.

3. A high tension tough steel having excellent resisting properties delayed rupture, consisting of 0.05 to 0.80 wt. percent C, 0.05 to 2.00 wt. percent Si, 0.30 to 2.00 wt. percent Mn, 0.05 to 6.00 wt. percent Cr, 0.01 to 0.30 wt. percent Ti, 0.005 to 0.30 wt. percent Zr and 0.0005 to 0.008 wt. percent B as basic elements, at least one element selected from the group consisting of Sn, Sb and As in the range of 0.03 to 0.50 wt. percent and further at least one element selected from the group consisting of Mo in an amount of 0.05 to 1.00 wt. percent Ni in an amount of 0.05 to 5.00 wt. percent, V in an amount of 0.005 to 1.00 wt. percent and Cu in an amount 0.03 to 0.50 wt. percent, the balance being Fe and unavoidable impurities.

4. A high tension tough steel having excellent delayed rupture resisting properties, consisting of 0.05 to 0.80 wt. percent C, 0.05 to 2.00 wt. percent Si, 0.30 to 2.00 wt. percent Mn, 0.05 to 6.00 wt. percent Cr, 0.01 to 0.30 wt. percent Ti, 0.005 to 0.30 wt. percent Zr and 0.0005 to 0.008 wt. percent B as basic elements, at least one element selected from the group consisting of Sn, Sb and As in the range of 0.03 to 0.50 wt. percent, further at least one element selected from the group consisting of Nb+Ta in an amount up to 1.00 wt. percent, W in an amount up to 1.00 wt. percent, Hf in an amount up to 0.50 wt. percent and Pd in an amount up to 1.00 wt. percent, and still further at least one element selected from the group consisting of Mo in an amount of 0.05 to 1.00 wt. percent, Ni in an amount of 0.05 to 5.00 wt. percent, V in an amount of 0.005 to 1.00 wt. percent and Cu in an amount of 0.03 to 0.50 wt. percent, the balance being Fe and unavoidable impurities.

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