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HIGH TENSION LOW TEMPERATURE TOUGH STEEL

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FIG. 1

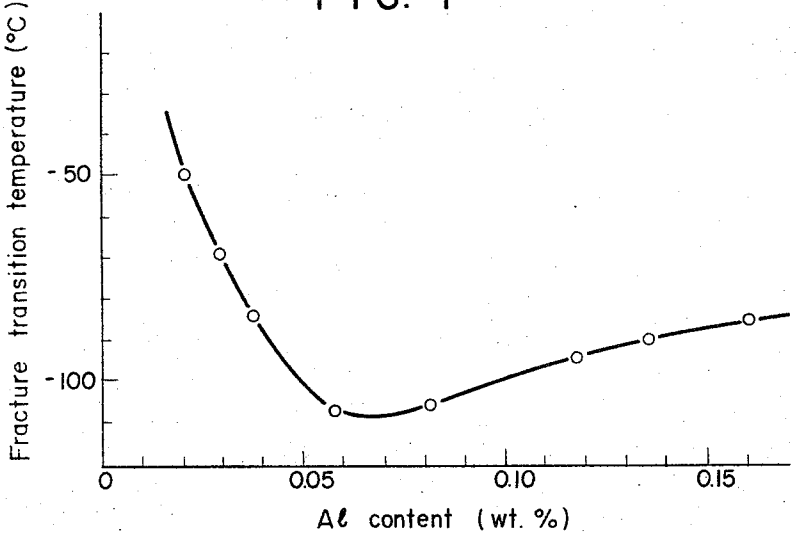
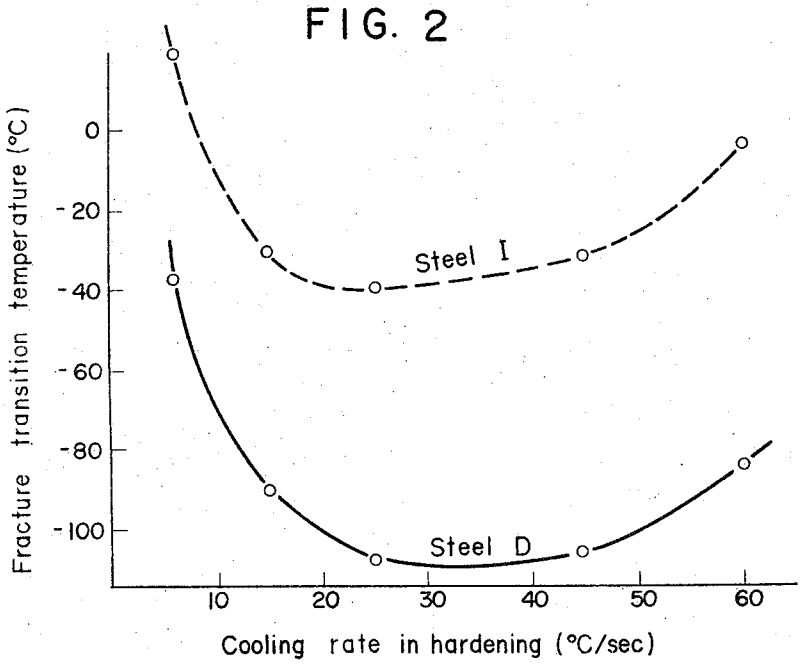


FIG. 2



INVENTORS

Susumu Goda
Hisashi Gondo
Yasumitsu Onoue

BY Wenderoth, Lind and Ponack, attorneys

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HIGH TENSION LOW TEMPERATURE TOUGH STEEL

Susumu Goda, Hisashi Gondo, and Yasumitsu Onoue, Kitakyushu, Japan, assignors to Yawata Iron & Steel Co., Ltd., Tokyo, Japan

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2 Claims. (Cl. 148—36)

ABSTRACT OF THE DISCLOSURE

A high tensile strength, low temperature tough steel consisting essentially of 0.05 to 0.25% by weight of C., 0.04 to 0.17% by weight of Al, 0.05 to 1.60% by weight of Mn, 0.20 to 1.60% by weight of Cr, and 0.05 to 1.00% by weight of Mo, the combined weights of Mn, Cr and Mo being no greater than 2.5% by weight, the remainder being Fe and inevitable impurities, and the steel having the aluminum in solid solution therein, the steel having been heated to a temperature above the A_3 point to austenitize it, thereafter hardened at a cooling rate of 10–60° C. per sec., and then tempered by heating to a temperature between 500° C. and the A_1 point.

This invention relates to a high tension low temperature tough steel.

In general, a steel material high in toughness at low temperature is needed for making tanks for use in storing liquefied petroleum gas of low boiling point. Heretofore, for this purpose a steel containing nickel or other alloying elements in a large amount or low carbon steel low in strength has been used. However, the use of steels of these kinds involved such economic disadvantages that not only the production cost was high, but also a thick plate was required.

An object of the present invention is to provide a steel having sufficient strength, toughness and weldability at a low production cost by reducing the addition of expensive alloying elements.

Other objects of the present invention will be made clear by the following explanation with reference to the attached drawings.

FIG. 1 is a diagram showing the relationship between the content of aluminum and fracture transition temperature and FIG. 2 a diagram showing the relationship between the cooling rate during hardening and the fracture transition temperature.

The steel according to the present invention is a high tension low temperature tough steel obtained from a steel material, which consists essentially of 0.05 to 0.25 wt. percent C., 0.10 to 0.70 wt. percent Si, 0.04 to 0.17 wt. percent Al, 0.05 to 1.60 wt. percent Mn, 0.20 to 1.60 wt. percent Cr, 0.05 to 1.0 wt. percent Mo with the Mn+Cr+Mo being $\gtreqless$ 2.5 wt. percent, as the basic constituents and further consisting of 0.03 to 0.15 wt. percent V, if necessary, and the rest being Fe and inevitable impurities, by heating said steel material to above the A_3 point to austenitize the same, thereupon subjecting the thus austenitized steel to a hardening at a cooling rate of from 10 to 60° C./sec. and then tempering the hardened steel in a temperature range of 500° C. to the A_1 point.

Among the above enumerated constituents, the range for C of 0.05 to 0.25 wt. percent is determined from the following necessities, that is, more than 0.05 wt. percent C is needed to maintain the hardenability, but the upper limit is determined to be 0.25 wt. percent from the view point of the weldability. More than 0.01 wt. percent Si is needed from the point of view of steel making, but more than 1.5 wt. percent is not desirable from the point of view of the toughness.

Mn is an economic element for use in effectively increasing the tensile strength. The addition of more than 0.5 wt. percent Mn displays the effect, but if the addition exceeds 1.5 wt. percent, the weldability will be impaired.

Cr is effective in increasing the strength of steel, if the addition exceeds 0.20 wt. percent, but more than 1.60 wt. percent is not desirable from the point of view of the notch-toughness. 0.05 to 1.0 wt. percent Mo is effective not only in increasing the strength but also improving the toughness.

Particularly, as regards Mn, Cr and Mo the sum of Mn+Cr+Mo is limited to 2.5 wt. percent in order to maintain the strength, low temperature toughness and weldability and to prevent the formation of excessive martensite. As is well known, when making a molten alloyed steel it is usual that a small amount of Ni such as 0.01 to 0.04 wt. percent is contained in the steel. Therefore, in such a case it is desirable to limit the sum of Mn+Cr+Ni to less than 2.5 wt. percent.

V is added to increase the strength, but the impact value will be somewhat deteriorated thereby. Consequently, V is to be added in an adequate amount according to the intended use of the steel produced. A range of from 0.03 wt. percent to 0.15 wt. percent is a suitable content of V for producing a steel having a relatively good impact value.

The addition of Al is one of the most important features of the present invention. The steel of the present invention contains Al more than any normal fine grained steel, that is, in a range of from 0.04 to 0.17 wt. percent. Al should be in a state of solid solution in the steel. Therefore, the content of N_2 or O_2, which eliminates the effect of Al by combining with Al, should be made as small as possible, and if these are coexistent, Al should be added in excess. The content of Al in an amount less than 0.04 wt. percent produces no effect, but if the content of Al exceeds 0.17 wt. percent, the viscosity of molten steel is increased when producing steel, which is apt to produce material defects or non-metallic impurities. Therefore, it is desirable to specify the upper limit of Al as 0.17 wt. percent.

The cooling rate for hardening the material heated to be austenite is specified as being in a range of from 10 to 60° C. per second, preferably from 15 to 25° C. per second. Then, the material quenched from austenite is tempered in a temperature range from 500° C. to the A_1 transformation point, whereby the desired strength and toughness may be simultaneously obtained.

FIG. 1 shows the effect of the Al content on the fracture transition temperature according to the V-notch Charpy test made on the steels which have a composition in the range specified by the present invention among those shown in Table 1. As evidently seen from the said FIG. 1, the fracture transition temperature is below —85° C. when the content of Al is in the range of from 0.04 to 0.15 wt. percent. No effect can be demonstrated even if the content of Al exceeded 0.17 wt. percent.

The steel D′ in Table 2 is that which has been obtained by especially adding Mn supplementally to a steel of the same composition as the steel D and in which the sum of Mn+Cr+Mo amounts to 2.7%. In this steel a deterioration was perceived in the low temperature toughness, even if the cooling rate was 45° C. per second.

FIG. 2 shows the fracture transition temperatures in correlation with the cooling rate in hardening the steels D and I shown in Table 1. The steel I which contains V showed a deterioration in the impact value as compared

with the steel D which does not contain V. However, the former steel showed a remarkable improvement in the tensile strength, as shown in the said figure. Therefore, the addition of V may be considered according to the intended use of the steel.

C, 0.10 to 0.70% by weight Si, 0.04 to 0.17% by weight of Al, 0.03 to 0.15% by weight of V, 0.05 to 1.60% by weight of Mn, 0.20 to 1.60% by weight of Cr, and 0.05 to 1.00% by weight of Mo, the combined weights of Mn, Cr and Mo being no greater than 2.5% by weight, the

TABLE 1

[Relationship between the amount added of Al and mechanical properties]

Sample	Chemical composition (wt. percent)									Heat-treatment			Tension test		V-notch Charpy test	
	C	Si	Mn	P	S	Cr	Mo	Al	V	Water hardening (° C.)	Tempering Temp. (° C.)	Cooling rate (° C.)	Yield point (kg./mm.²)	Tensile strength (kg./mm.²)	Elongation (percent)	Fracture transition temp. (° C.)
A	0.18	0.35	0.85	0.019	0.011	1.08	0.40	0.021	------	900	650	55	74	84	24.5	−49
B	0.18	0.34	0.86	0.017	0.011	1.08	0.40	0.029	------	900	650	50	75	86	24.7	−68
C	0.17	0.35	0.87	0.016	0.010	1.07	0.41	0.038	------	900	650	45	76	86	23.4	−78
D	0.17	0.34	0.86	0.017	0.012	1.08	0.41	0.058	------	900	650	20	77	87	23.6	−107
E	0.18	0.36	0.84	0.019	0.012	1.09	0.40	0.082	------	900	650	20	77	85	23.7	−105
F	0.17	0.35	0.85	0.016	0.011	1.07	0.41	0.118	------	900	650	15	76	84	24.8	−94
G	0.18	0.35	0.84	0.020	0.009	1.06	0.41	0.136	------	900	650	18	76	86	24.0	−90
H	0.18	0.36	0.86	0.018	0.010	1.08	0.40	0.161	------	900	650	30	77	85	23.1	−84
I	0.18	0.21	0.71	0.021	0.010	1.10	0.47	0.053	0.13	900	650	25	97.1	102.5	18.0	−33

TABLE 2

[Relationships between the cooling rate hardening, the amounts added of alloying elements and mechanical properties]

Sample	Hardening temperature (° C.)	Cooling rate (° C./sec.)	Tempering temperature (° C.)	Yield point (kg./mm.²)	Tensile strength (kg./mm.²)	Elongation (percent)	V-notch Charpy test, Fracture transition temperature (° C.)	Mn+Cr+Mo (percent)
D	900	45	650	77	87	23.6	−107	2.35
D′	900	45	650	79	88	22.1	−73	2.70

What is claimed is:

1. A high tensile strength, low temperature tough steel consisting essentially of 0.05 to 0.25% by weight of C, 0.04 to 0.17% by weight of Al, 0.05 to 1.60% by weight of Mn, 0.20 to 1.60% by weight of Cr, and 0.05 to 1.00% by weight of Mo, the combined weights of Mn, Cr and Mo being no greater than 2.5% by weight, the remainder being Fe and inevitable impurities and the steel having the aluminum in solid solution therein, the steel having been heated to a temperature above the A_3 point to austenitize it, thereafter hardened at a cooling rate of 10–60° C. per sec., and then tempered by heating to a temperature between 500° C. and the A_1 point.

2. A high tensile strength, low temperature tough steel consisting essentially of 0.05 to 0.25% by weight of remainder being Fe and inevitable impurities and the steel having the aluminum in solid solution therein, the steel having been heated to a temperature above the A_3 point to austenitize it, thereafter hardened at a cooling rate of 10–60° C. per sec., and then tempered by heating to a temperature between 500° C. and the A_1 point.

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CHARLES N. LOVELL, *Primary Examiner.*