United States Patent Office

3,216,823

Patented Nov. 9, 1965

3,216,823

LOW ALLOY STEEL

John A. Gulya, Lancaster, and Edgar L. Fogleman and John C. Bomberger, Downingtown, Pa., assignors to Lukens Steel Company, Coatesville, Pa., a corporation of Pennsylvania

No Drawing. Filed Jan. 19, 1965, Ser. No. 426,686
7 Claims. (Cl. 75—124)

This invention relates to a balanced low alloy steel having improved toughness and formability as well as high strength and good weldability properties. More particularly, the present invention relates to a heat treated, quenched and tempered, high strength steel which demonstrates strength, toughness, and formability characteristics of a high order.

The steel of the instant invention is considered to be an alloy steel. The composition of this steel includes minor amounts of alloying elements including zirconium and boron as well as small percentages of molybdenum, vanadium and other elements. These elements and the heat treatment characterize the low alloy steel as well balanced having temperability, toughness, weldability, hardness, ductility and high strength. It has been found that the particular chemistry and processing of the steel disclosed herein are both essential. Prior art steels usually possess some of the desirable properties at the expense of others. One particular steel may demonstrate good strength but exhibit poor results in the bend test or Charpy V-notch impact test at low temperatures. The steel disclosed herein is particularly tough and strong even at low temperatures.

It is an object of the present invention to provide a weldable heat treated low alloy steel having high yield and tensile strengths.

It is another object of the present invention to provide a heat treated low alloy steel which was unexpected formability combined with excellent toughness and other qualities over a wide temperature range.

It is still another object of the present invention to provide an economically attractive steel having superior strength and ductility properties, which steel is heat treated by quenching and tempering.

The above and other objects will be apparent from the following description.

Low alloy, high strength, weldable steels find many applications in the manufacture of vehicles, ships and other objects that may be fabricated by welding. The steels heretofore available for the above applications sometimes have tensile and yield strengths of a fairly high order but do not exhibit the requisite temperability or toughness. The present day requirements of steel demand severe formability and impact resistance at low temperatures in addition to the usual yield and tensile strength determination. With a view to overcoming the deficiencies of the prior art and to provide a superior balanced low alloy steel, it has been found that a heat treated steel having the below chemistry is economically attractive and superior.

C	.10–.22.
Mn	.90–1.30.
Si	0.2–0.4.
Cr	.30 max.
Mo	.22–.38.
V	.02–.09.
B	0.005.
Ni	.30 max.
Zr	0.03–0.15.
Al	Fine grain practice—0.02 min.

Balance iron and incidental impurities with P and S being about 0.040 max. and Cu being about 0.35 max.

In the above ranges, the following is the preferred chemistry:

C	0.15–0.2
Mn	1.1–1.3
Si	0.2–0.4
Cr	0.05–0.3
Mo	0.25–0.35
V	0.02–0.07
B	0.003–0.005
Ni	0.1–0.25
Zr	0.05–0.1
Al	0.03 min.
Cu	0.35 max.
P	0.025 max.
S	0.025 max.

Balance iron and incidental residuals. All figures listed herein are based on percentages by weight unless indicated otherwise.

Steel plates made in accordance with the present invention are heat treated. Heat treatment is carried out at a temperature of about 1600–1700° F. and the plates are quenched, preferably by water. The plates are then tempered at about 1100–1300 F. preferably 1125–1275° F. in order to have the balanced properties shown in Table 4.

The unusual strength and other properties of steel having the following ladle analysis is given in Tables 1 and 2.

C	0.17	Mo	0.31
Mn	1.19	V	0.032
Si	0.30	B	0.001
P	0.01	Zr	0.029
S	0.007	Al	0.041
Ni	0.15	Cu	0.08
Cr	0.13		

TABLE 1

(*Tensile properties*)

Gage	Temper., ° F.	Yield St. (K s.i.)	Ten. St. (K s.i.)	Elong. % 2″	Red. Area
¼″	1,260	105.7	112.2	20	67.2
½″	1,260	106.2	114.3	26	67.8
1¼″	1,220	100.9	112.8	21	68.4
2″	1,200	95.1	109.5	23	69.5

The tensile tests in the preceding table were taken in the longitudinal direction, using plate type specimens for ¼″ and ½″ plate, and .505 diameter rounds for 1¼″ and 2″ plate. Standard Charpy V-notch tests were performed on specimens corresponding in gage and treatment to Table 1, with the results given in Table 2 for longitudinal (L) and transverse (T) specimens.

TABLE 2

(*Impact properties*)

Gage	Size	Dir.	Temp., ° F.				
			80	+10	−50	−110	−140
¼″	½	L	41	40	40	32	12
¼″	½	T	26	29	26	18	8
½″	Full	L	92	95	88	46	21
½″	Full	T	63	60	47	21	14
1¼″	½	L	45	45	45	42	26
1¼″	Full	L	84	82	67	31	14
1¼″	Full	T	76	72	56	30	8
1¼″	Full	L	45	------	------	18	10
2″	Full	L	75	57	15	------	------

To further demonstrate the ductility and formability of the instant steel, bend tests were performed on the ¼″

and ½" plate described by Tables 1 and 2. In these tests, the ¼" plate was doubled back flat on itself to an outside radius gage ratio of 1.85 without failure. On ½" plate bent to an outside radius: gage ratio of about 1.5 no failure was evident until the plate was further bent to have an outside radius: gage ratio of 1.35.

As evidence of the good weldability of the instant steel, underbead crack, cruciform, butt, and T-fillet weld tests were conducted on the previously described plate. Using commercially available electrodes for both manual and submerged arc welding technique, ductile 100% efficient joints were obtained in butt welds and no significant cracking was observable in the underbead, cruciform, or T-fillet tests. Performance of this type is indicative of suitability for field application. Trials of the instant steel in customer shops have confirmed these laboratory weldability tests.

Reduction of residual stress in fabricated structures frequently requires stress relief treatment consisting of heating to 50 or 100° below the tempering temperature followed by slow cooling. This treatment frequently causes alloy steels to become embrittled. To investigate the response of the instant steel to such treatments, samples of 1¼" plates were stress relieved at 1150° F., subjected to various cooling rates, and tested (longitudinal only). The following results show that a stress relief has no significant effect on toughness or ductility.

TABLE 3

Condition	YS (K s.i.)	TS (K s.i.)	E, percent 2"	RA	CVN		
					80°	0°	−80°
Q. and T. only (control)	102.8	113.9	20	67.2	84	81	49
S.R. (water quench)	95.4	110.3	22	67.0	84	82	50
S.R. (air cooled)	101.0	111.5	23	67.5	90	88	75
S.R. (furnace)	99.0	110.3	22	68.5	89	77	33

For purposes of illustrating the broad range of properties obtainable a tempering study was also carried out on 1¼" gage (longitudinal only) austenitized at 1650° F. with the results shown in Table 4 below.

TABLE 4

Temp.	YS (K. s.i.)	TS (K. s.i.)	E, percent 2"	RA	CVN		
					80°	0°	−80°
None	142.3	189.8	14	54.7	39	27	20
200	135.2	182.5	14	55.9	39	31	22
400	147.4	185.9	14	54.6	34	24	19
60	162.1	189.9	14	53.6	27	22	9
800	153.3	164.9	15	58.8	45	28	21
1,000	134.3	142.5	17	62.2	58	54	36
1,100	131.5	139.2	19	63.2	65	62	42
1,150	129.0	136.4	19	63.9	66	64	47
1,200	119.5	127.0	20	65.8	75	78	64
1,250	106.6	116.0	22	69.2	90	83	80
1,300	94.5	106.1	24	71.8	98	101	97

In order to confirm that the unusual properties of the steel disclosed herein are unequaled by other steels having similar chemistry, a comparison of test results was compiled. The residual contents of P, S, and Cu as well as Al were comparable in each sample and within the ranges set forth above.

TABLE 5

Material	C	Mn	Si	Ni	Cr	Mo	V	Ti	Zr	B
Application Steel	.18	1.28	.36	.19	.15	.34	.02	----	.03	.003
Prior Art Steel	.18	.63	.17	----	.46	.21	.06	.03	----	.003

TENSILE PROPERTIES

Material	Gage, inches	Temper., °F.	.2 Yield	Tensile	Elong.	R.A. percent
A. Steel	¼"	1,260	103,600	112,200	20 (percent, 2").	67.2
A. Steel	½"	1,260	107,400	115,900	27 (percent, 2").	71.0
P.A. Steel	½"	1,175	96,300	106,900	21.5 (percent, 1").	71.5
P.A. Steel	1"	1,100	92,800	105,300	22.5 (percent, 2").	68.8
A. Steel	1¼"	1,220	102,000	114,100	21 (percent, 2").	68.8

IMPACT PROPERTIES (CVN)

[Typical impact strength, ft.-lbs. at indicated temperature]

Material	Gage	RT	−50° F.
Application Steel	1¼" Plate	89	55
Prior Art Steel	1¼" Plate	35	15

In bend tests with varying orientation to direction of rolling, the application steel showed no break when ¼" gage was bent in die 180° both in longitudinal and transverse directions. In contrast, the prior art steel plate of the same size showed numerous tears in the same test before being bent 180°. Transverse test developed failure in prior art steel before longitudinal test.

We have disclosed a low alloy steel having unusual well-balanced properties which is attributed to heat treatment and a specific chemistry. However, it will be understood that the above described embodiments are illustrative of but specific forms of our invention and variations thereof within the scope of the invention will be apparent to one skilled in the art.

We claim:

1. A heat treated steel having the chemistry:

C	0.12–0.22
Mn	0.90–1.30
Si	0.2–0.4
Cr	0.30 max.
Mo	0.22–0.38
V	0.02–0.09
B	0.0005–0.005
Ni	0.30 max.
Zr	0.03–0.15
Al	0.02 min.
Cu	0.35 max.
P	0.040 max.
S	0.040 max.

The balance being iron and incidental residuals.

2. The invention of claim 1 wherein plates of said steel are quenched from about 1600–1700° F.

3. The invention of claim 2 wherein the plates are water quenched.

4. The invention of claim 2 wherein plates of said steel are tempered at about 1100–1350° F.

5. A quenched and tempered steel having the chemistry:

C	0.15–0.2
Mn	1.1–1.3
Si	0.2–0.4
Cr	0.05–0.3
Mo	0.25–0.35
V	0.02–0.07
B	0.003–0.005
Ni	0.1–0.25
Zr	0.05–0.10
Al	0.03 min.
Cu	0.35 max.
P	0.025 max.
S	0.025 max.

The balance being iron and incidental residuals.

6. The invention of claim **5** wherein plates of said steel are quenched from about 1600–1700° F. and tempered at about 1125–1275° F.

7. The invention of claim **6** wherein the plates are water quenched.

References Cited by the Examiner

UNITED STATES PATENTS

1,831,946	11/31	Breeler	75—124
1,959,398	5/34	Whiteley	75—123
2,853,379	9/58	Althouse	148—36
2,858,206	10/58	Boyce et al.	148—36
3,110,635	11/63	Gulya	148—36

DAVID L. RECK, *Primary Examiner.*

BENJAMIN HENKIN, *Examiner.*