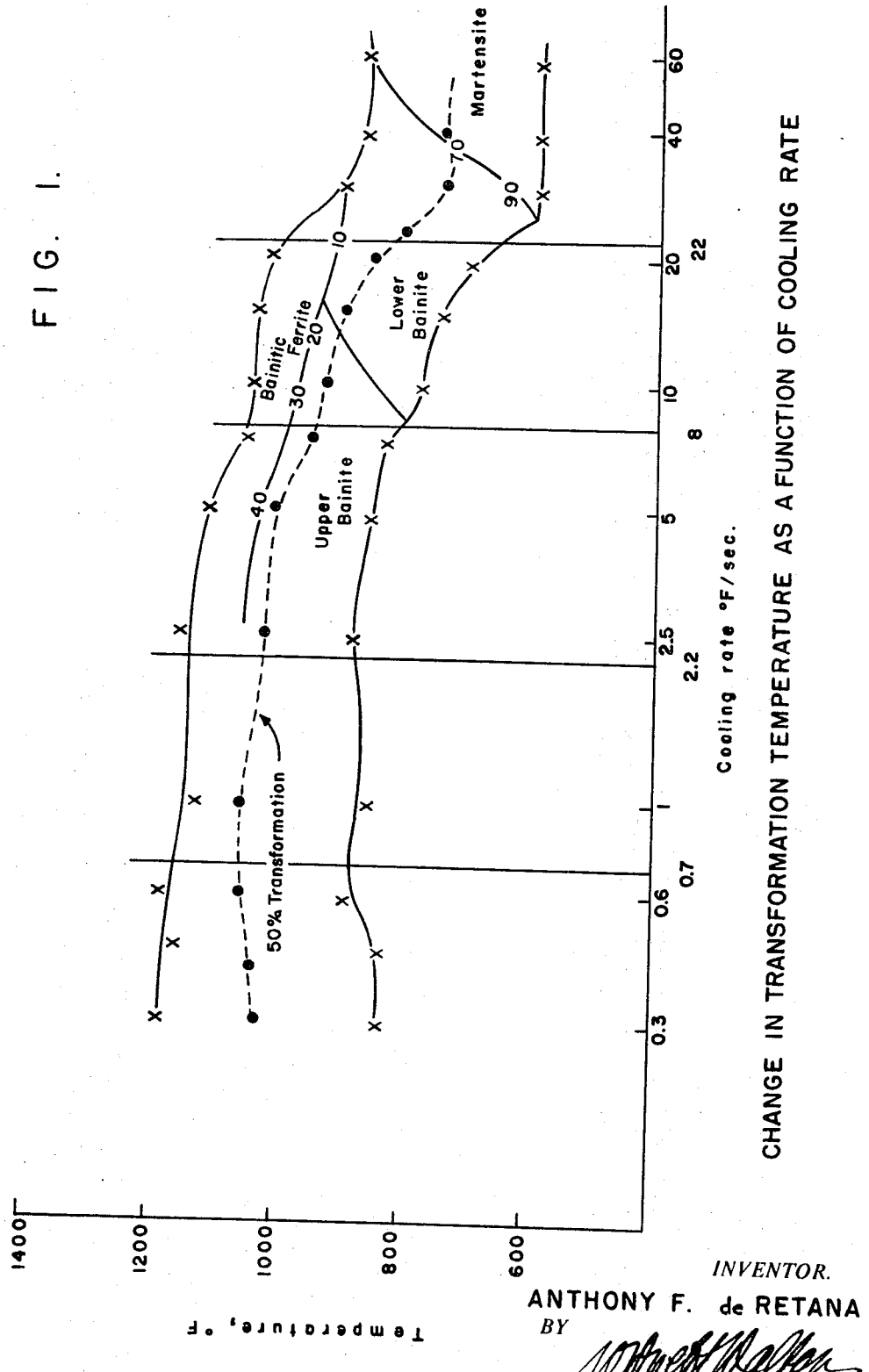
Nov. 10, 1970 A. F. DE RETANA 3,539,404

METHOD OF MAKING A LOW ALLOY STEEL

Filed May 15, 1967 2 Sheets-Sheet 1

FIG. 1.



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FIG. 3.

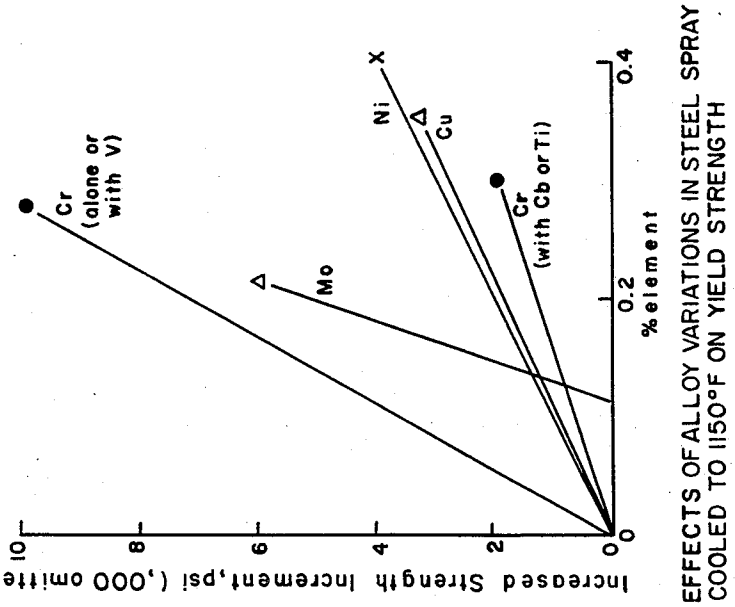
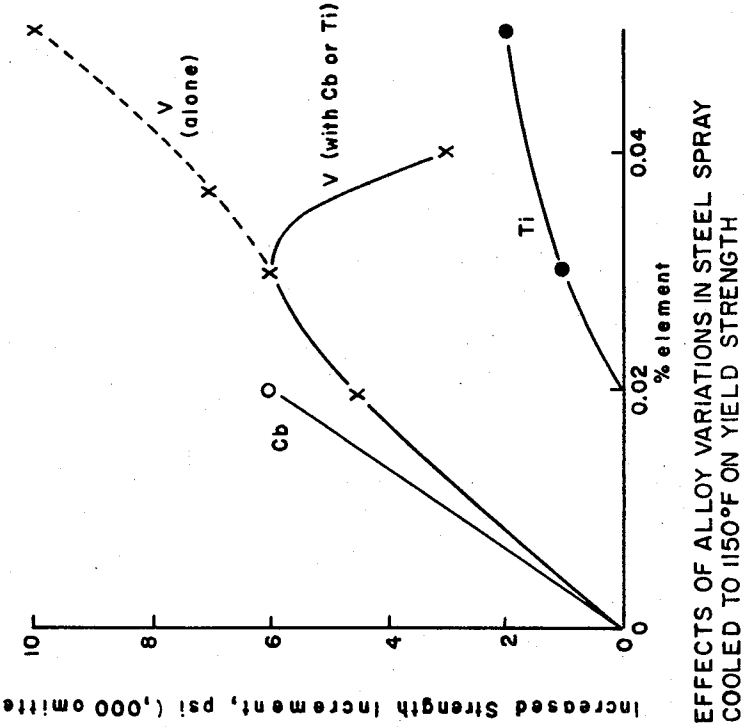


FIG. 2.



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METHOD OF MAKING A LOW ALLOY STEEL

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Int. Cl. C21d 1/02
U.S. Cl. 148—12.4 4 Claims

ABSTRACT OF THE DISCLOSURE

A low cost, low alloy steel containing not more than about 0.25% molybdenum (Mo) in the presence of carbonitride formers, carbide formers or both in relatively small quantities, as well as a method of treating the steel to attain high yield strength (80,000 p.s.i. or more) and good low temperature impact toughness (transverse charpy V-notch 15 ft. lb. at —50° F. or less).

BACKGROUND OF THE INVENTION

The invention is directed to improvements in the production of alloy steels low in Mo by reducing the amount thereof heretofore thought essential and provision of a novel method of treating the steel whereby the properties of strength and toughness heretofore attained by the employment of relatively large amounts of Mo are imparted to it during the cooling stages to which it is subjected following a hot working or other mill process wherein it it heated to an elevated temperature, typically one in the neighborhood of 2100° F.

SUMMARY OF THE INVENTION

A principal object of the invention therefore is to provide for subjecting a low Mo steel of predetermined chemical composition containing not over 0.25% Mo to a predetermined cooling operation whereby when the steel finally emerges therefrom its yield strength, tensile strength and impact transition temperature are within optimum ranges, for example, yield strength of approximately 80,000 p.s.i. or more, tensile strength in the neighborhood of 100,000 p.s.i. and impact transition temperature —50° F. or less.

It is well known that addition of Mo to steel in amounts approximating 0.5% and upwards with about 0.002% of boron (B) present, results in production of steel of good hardenability, strength and toughness but as far as is known these properties have not been attained to a like degree with less than said quantities of Mo and B, and it is therefore further within contemplation of the invention to provide steel containing not more than about 0.25% Mo and preferably 0.0005 to 0.0015% B with other alloying elements in small amounts and to subject it to a novel processing whereby good yield and tensile strengths and low impact transition temperatures are attained at a cost for the finished steel materially lower because of the lesser amounts of expensive alloying elements used in its production than heretofore believed essential for securement of comparable results.

Other objects, purposes and advantages of the invention will hereinafter more fully appear or be understood from the following more specific description in which reference will be had to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph based on determination of the effects on transformation temperature of changes in the cooling rate after heat processing of the low alloy steel of my invention;

FIG. 2 is a graphic representation of the effect on yield strength resulting from use of various alloying elements in said low alloy steel processed in accordance with the invention, and

FIG. 3 is a corresponding chart of the effects thereon of various amounts of other alloying elements in said low alloy steel subjected to like processing.

DESCRIPTION OF THE PREFERRED EMBODIMENT

More particularly the invention will now first be described with more detailed reference to the several alloying elements employed in the steel and the amounts of each contemplated thereby and then to the processing to which the steel containing them is subjected to attain the results set forth and summarized in said graphs, it being understood that steel of any of the several specific analyses given is within the scope of the invention and may be subjected to treatment in accordance with the method thereof utilizing any of several specifically slightly differing processing steps as will hereinafter be more fully explained.

Thus, in general, the invention is directed and is in fact confined to steel containing at least some of the elements within the range of the percentages set forth in the following table in which, it will be understood, the difference between the totals of said elements and 100% is substantially only iron with perhaps very small percentages of sulfur, phosprorus and the like constituting impurities; it is therefore unnecessary to include percentages of iron in each instance:

TABLE 1

C	0.13–0.22
Mn	0.69–1.28
Si	0.15–0.40
Cr	0.00–0.37
Mo	0.11–0.25
B	0.0005–0.0015
Cb	0.019–0.021
Al	0.032–0.052
V	0.023–0.050
Ti	0.010–0.050

In addition to these elements, Ni and Cu may be added without detriment to the physical properties and will improve the corrosion resistance as is well known by those versed in the art; it will of course be appreciated that inclusion of an element or elements in the foregoing tabulation is not intended to mean that each or all except C, Mn, Si, Mo, B and Ti are necessary in a given steel.

A number of samples of steels of slightly different analysis yet all within said ranges and after treatment in accordance with my novel method, were subject to tests to determine factors on which the aforesaid graphs are based; two such steels hereinafter designated steel A and steel B respectively, substantially identical in analysis with the exception that steel A contained 0.37% chromium while steel B was free of that element, contained the following in the amounts given:

Element:	Percent
C	0.13
Mn	0.98
Si	0.27
Mo	0.21
B	0.0015
Cb	0.02
Al	0.017
V	0.023
Ti	0.026

More specifically, test pieces of these steels simulating plates of gages 5/16", 1/2" and 5/8" respectively were heated

to 2100° F., cooled slightly, and hotworked prior to being subjected to treatment in accordance with the invention with the following results, the temperature of the pieces at the initiation of the treatment being 1700° F. in all cases:

TABLE 2

Steel	Spray cool time, sec.	To ° F.	Spray cool rate, ° F./sec.	Air cool time, min./sec.	To ° F.	Air cool rate, ° F./sec.
5/16" Plate:						
A1 and B1	35	1,050	18.6	2.40	750	1.88
A2 and B2	27	1,150	20.4	3.20	750	2.00
A3 and B3	21	1,250	21.4	3.50	750	2.18
½" Plate:						
A4 and B4	50	1,050	13.0	5.00	750	1.00
A5 and B5	40	1,150	13.8	6.00	750	1.11
B6	25	1,250	18.0	8.00	800	0.94
5/8" Plate:						
A7 and B7	100	1,050	6.5	6.20	800	0.66
A8 and B8	70	1,150	7.9	7.50	800	0.75
A9 and B9	55	1,250	8.2	9.00	800	0.83

When the foregoing pieces, after treatment, were tested to determine yield strength and tensile strength, and some to determine in addition impact transition temperature, the following results were observed:

TABLE 3

	Yield strength, p.s.i.	Tensile strength, p.s.i.	Impact transition temperature (° F.) [1]
A1	91,000	113,000	
B1	91,000	110,000	
A2	89,000	107,000	
B2	91,000	108,000	
A3	87,000	107,500	
B3	86,000	103,000	
A4	97,000	113,000	−110
B4	95,000	110,000	−120
A5	88,000	107,000	−90
B5	89,000	106,000	−90
B6	82,000	101,000	−120
A7	89,000	107,000	
B7	93,000	108,100	
A8	85,400	105,000	
B8	89,300	106,100	
A9	80,500	99,000	
B9	86,000	104,500	

[1] ⅓ size charpy V-notch, 5 ft. lbs.

Heating to 2100° F.–2200° F., in all instances precedes the predetermined controlled cooling of the steel in accordance with the invention and this may occur as an incident to other mill processes, for example as residual heat imparted in the normal course of production as in a soaking operation. The steel is then mechanically deformed preparatory to the subsequent specified cooling, and it is substantially immaterial what specific apparatus be employed for the spray cooling provided the rates of cooling be not substantially different from those I have found appropriate and so approximately within the limits of the treatments set forth in the foregoing Table 2.

The graph of FIG. 1, based on the effect of various cooling rates in ½ steel plate of analysis within the ranges of Table 1 and containing, more specifically, 0.21% Mo and 0.0015% B, demonstrates that the cooling rates within the scope of the invention, i.e., about 8°–22° F./sec. during the spray cooling to a temperature above 1050° F. and about 0.7°–2.2° F./sec. during subsequent air cooling confers a structure in the steel which is free of martensite and consists mainly of acicular ferrite and upper bainite.

The graphs of FIGS. 2 and 3 are designed to show the effects, plotted in increments of increasing yield strength in p.s.i., of inclusion in the low Mo steel of my invention of varying amounts of certain of the alloying elements heretofore mentioned; these results were derived from tests of samples simulating ½" plate.

Hence within the scope of my invention is the provision of steel of composition within the analysis of Table 1 and treatment thereof by controlled cooling from 1700° F. or higher initially at a relatively rapid rate by spray cooling for a limited period followed by controlled slower cooling in air for a considerably longer one, all to produce low alloy molybdenum steel of characteristics making it eminently suitable for fabrication into articles of commerce.

I claim:

1. A method of treating a steel composition containing 0.13–0.22% carbon, 0.69–1.28% manganese, 0.15–0.40% silicon, 0.11–0.25% molybdenum, 0.0005–0.0015% boron, 0.010–0.050% titanium, about 0.015–.050% of at least one element selected from the group consisting of columbium and vanadium, which method comprises:
   (a) heating to about 2200° F.
   (b) hot-working to about 1700° F.;
   (c) spray-cooling from about 1700° F. to a range about 1250–1000° F. at a rate of about 6.5–22° F. per second; and
   (d) controllably air-cooling to 800–750° F. at a rate of about 0.66–2.2° F. per second, to thereby produce a steel product having a micro-structure of acicular ferrite and upper bainite and characterized by the absence of martensite and by a yield strength of at least 80,000 p.s.i.

2. A method as defined in claim 1 in which the steel contains columbium selected from said group in the proportion of about 0.015–0.030%.

3. A method as defined in claim 1 in which the steel contains vanadium selected from said group in the proportion of about 0.023–0.050%.

4. A method as defined in claim 1 in which the steel contains columbium selected from said group in the proportion of about 0.015–0.030% and vanadium selected from said group in the proportion of about 0.023–0.050%.

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HYLAND BIZOT, Primary Examiner