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HIGH STRENGTH ALLOY STEEL FOR STRUCTURAL AND PRESSURE VESSELS

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3 Claims. (Cl. 75—124)

This invention relates to alloy steels and more particularly to low alloy, high strength structural quality, or flange and firebox quality steels. The overall production of the steels of this invention would be for the production of rolled plates, sheets, bars and rods. The invention further pertains to the production of forgings and structural shapes, in the heat treated condition, i. e., normalized, accelerated cool normalized, and stress relieved or tempered.

An object of the invention is the production of a molybdenum-nickel-vanadium-titanium steel which is in the low alloy-high strength category, and which can be developed for structural and pressure vessel uses of the type which require a high yield point combined with good ductility and weldability.

A further object of the invention is the production of such alloy steel wherein a specific combination of alloying elements can be varied within definite ranges to provide proper weldability and strength for varying thicknesses of plate.

The foregoing objects are achieved in the present invention by the provision of a new and useful combination of alloying elements which together with iron are combined to produce an alloy steel having the desired tensile properties, toughness, ductility, high yield strength with good impact properties down to —40° F.

The molybdenum-nickel-vanadium-titanium steel of this invention can be produced by either the open hearth, or the electric furnace, using a fine grain practice, including making the proper addition of deoxidizer, such as aluminum, in order to obtain an inherent grain size of McQuaid-Ehn Number 5 or finer.

A steel made for overall purposes that is in accordance with the present invention will conform to the following chemical analysis range:

	Percentage
Carbon	0.08–0.30
Manganese	0.90–1.40
Phosphorous	0.040 maximum
Sulphur	0.050 maximum
Silicon	0.15–0.35
Nickel	1.25–1.75
Vanadium	0.05–0.13
Molybdenum	0.10–0.30
Titanium	0.005–0.05
Copper	0.35 maximum
Aluminum	0.03–0.10
Iron	[1] Remainder

[1] With the exception of incidental steel making elements.

It has been found that alloy steels within the foregoing ranges provide a high tensile steel with good impact properties down to —40° F. The yield strengths of these steels are equal to or superior to other high strength steels now being used in the industry.

An alloy material for the production of thin section sheet or plates, bars, rods or shapes under ½" maximum

thickness or cross-section would have chemical analysis and ranges of:

	Percentage
Carbon	0.80 –0.15
Manganese	0.90 –1.20
Silicon	0.15 –0.35
Nickel	1.25 –1.75
Vanadium	0.05 –0.10
Molybdenum	0.10 –0.20
Titanium	0.005–0.02
Aluminum	0.03 –0.10

Remainder iron containing incidental impurities.

Material for the making of larger cross section plates, bars, rods or shapes would have chemical analysis ranges of:

	Percentage
Carbon	0.18 –0.30
Manganese	1.20 –1.40
Silicon	0.20 –0.35
Nickel	1.50 –1.75
Vanadium	0.08 –0.13
Molybdenum	0.20 –0.30
Titanium	0.005–0.05
Aluminum	0.04 –0.10

Remainder iron containing incidental impurities.

Mechanical properties

The mechanical properties of the alloys having the above noted ranges after normalizing at 1650° F.–1725° F., and tempering or stress-relieving between 1100° F. and 1250° F. will be as follows:

	Plates or Sections ¼" and Under in Thickness	Plates or Sections over ¼" to 1½", incl., in thickness	Plates or Sections over 1½" to 3", incl., in thickness
Tensile Strength, p. s. i.	100,000–125,000	100,000–125,000	100,000–125,000
Yield strength, min., p. s. i. at 0.2 percent offset	80,000	80,000	75,000
Elongation in 2", min. percent	18.0	20.0	20.0
Reduction in area, min. percent	45.0	55.0	55.0

The material after heat treatment will have impact properties, as tested by Charpy keyhole type test, of minimum 15 ft. lbs. at —40° F.

Cold bend tests will meet the requirements shown below when bent 180 degrees to an inside diameter which will have the following relation to the thickness of the specimen:

Thickness	Ratio of pin diameter to thickness of specimen
Up to 1½", incl	2
Over 1½" to 3", incl	3

The mechanical properties shown below are for material over 3" in thickness after accelerated cooling from a normalizing temperature of 1650–1750° F., followed by tempering or stress relieving between 1100–1250° F. Accelerated cooling from the normalizing temperature is the cooling of steel products from this temperature to below 1000° F. by use of air blast, water spray or water dip, within a short time—usually less than ten minutes.

	Plates or sections over 3" in thickness
Tensile strength, p. s. i.	100,000–125,000
Yield strength, min., p. s. i.	80,000
Elongation in 2", min. percent	20.0
Reduction in area, min. percent	55.0

The material after this heat treatment will have impact properties, as tested by Charpy keyhole test, of minimum 15 ft. lbs. at —40° F.

Cold bend test of reduced section, i. e., ½" square bars, shall bend 180 degrees to an inside diameter of once the thickness of the specimen.

The advantageous features of steel materials of this composition are:

(1) High yield strength and ultimate strength with good impact properties down to —40° F. These are obtained by use of air cooling from the normalizing temperature and stress-relief rather than by a liquid quench and draw heat treatment.

(2) By use of an accelerated cooling in air blast, water spray or water dip from 1650° F. to below 1000° F., heavy gauge materials—or materials over 3" thick or in same cross-section—can be produced having good low temperature impact properties.

(3) The properties of the material are obtained from a structure consisting of ferrite and finely dispersed pearlite, rather than one resulting from tempered martensite, such as would be obtained on fully quenched and drawn material.

(4) The fabrication and welding of this material are simplified with the above structure.

Fabrication

Plates 1" and under in thickness can be sheared to size. Plates over 1" will be gas cut to size. The gas cutting will be preceded by pre-heating the plate to 200° F. Forming of heads or bending of plates can be accomplished either cold or hot.

Welding characteristics are good if proper weld rod and good welding technique are applied.

The invention may be embodied in other specific forms without departing from the essential characteristics thereof. Hence, the present embodiments are therefore to be considered in all respects merely as being illustrative and not as being restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all modifications and variations as fall within the meaning and purview and range of equivalency of the appended claims are therefore intended to be embraced therein.

What it is desired to claim and secure by Letters Patent of the United States is:

1. A low alloy high structural strength steel suitable for structural or pressure vessel uses and having improved weldability, said steel containing 0.80–0.30 percent carbon, 0.90–1.40 percent manganese, up to 0.040 maximum percent phosphorous, up to 0.050 percent maximum sulphur, 0.15–0.35 percent silicon, 1.25–1.75 percent nickel, 0.05–0.13 percent vanadium, 0.10–0.30 percent molybdenum, 0.005–0.05 percent titanium, up to 0.35 percent maximum copper, 0.03–0.10 percent aluminum, and the remainder iron and incidental impurities.

2. A low alloy high structural strength steel suitable for thin section sheets, bars, rods or shapes having a maximum cross section of 3", said steel containing .08–0.15 percent carbon, 0.90–1.20 percent manganese, 0.15–0.35 percent silicon, 1.25–1.75 percent nickel, 0.05–0.10 percent vanadium, 0.10–0.20 percent molybdenum, 0.005–0.02 percent titanium, 0.03–0.10 percent aluminum, and the remainder iron and incidental impurities.

3. A low alloy high structural strength steel suitable for plates, forgings, shapes and bars of heavy cross section in excess of 3" thickness, said steel containing 0.18–0.30 percent carbon, 1.20–1.40 percent manganese, 0.20–0.35 percent silicon, 1.50–1.75 percent nickel, 0.08–0.13 percent vanadium, 0.20–0.30 percent molybdenum, 0.005–0.05 percent titanium, 0.04–0.10 percent aluminum, and the remainder iron and incidental impurities.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,853,379 September 23, 1958

Joseph G. Althouse

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 4, in the tabulation, under the heading "Percentage", first item, for "0.80-0.15" read -- 0.08-0.15 --; column 4, line 7, for "0.80-0.30" read -- 0.08-0.30 --.

Signed and sealed this 6th day of January 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents