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HIGH-TEMPERATURE STEEL

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1 Claim. (Cl. 75—123)

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This invention relates to steels for elevated temperature service having improved hardenability characteristics.

The medium alloy ferritic or pearlitic steels used for elevated temperature service usually contain sufficient molybdenum to give enhanced creep resistance. A commonly used grade of this steel contains from .05 to .20% carbon, .15 to .50% manganese, .05 to .30% silicon, .40 to .60% molybdenum, .25% balance iron except for residual amounts of other elements and impurities. Such composition provides most of the mechanical properties needed for pressure vessels but the high hardenability thereof renders it unsuitable for use in structures subjected to dynamic loading after the steel has been rapidly cooled from the above the upper critical temperature.

It is accordingly an object of this invention to provide a molybdenum steel of the type designed for high temperature steel which has a greatly reduced hardenability.

It is a further object to provide a molybdenum-bearing steel of the type designed for high temperature service having a reduced hardenability which is economical to produce.

I have discovered that the foregoing and further objects can be obtained by alloying both titanium and cobalt with the steel. While stabilizing additions of titanium have heretofore been made, the conjoint additions of cobalt and titanium of my invention in amounts of between .25 to .50% titanium and .25 to .60% cobalt give greatly improved dynamic loading characteristics as shown by the hereinafter set forth impact and hardenability properties.

To illustrate the desirable results obtained by

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the cobalt and titanium tests based on the following steels are included herein:

Steel No.	Type	C	Mn	Si	Mo	Ti		Co
						Soluble	Total	
1	C	.13	.15	.11				
7	C-Mo	.15	.21	.10	.43	.002	.012	
2	Mo-Co	.12	.14	.10	.44	.009	.013	.45
5	Mo-Ti	.12	.20	.067	.44	.007	.27	
3	Mo-Co-Ti	.11	.27	.093	.42	.006	.29	.44
4	Mo-Co-Ti	.10	.21	.11	.22	.004	.30	.52
6	Mo-Co-Ti	.11	.25	.14	.61		.26	.28

The mechanical properties of these steels determined on 1" square bars normalized by holding for 15 minutes at 1700° F. followed by air cooling and machined into standard 0.505" round test bars and V-notch Charpy impact specimens are given in the following Table A.

Table A

Steel No.	Type	Tensile Strength, lbs./inch square	Yield Point, lbs./inch square	Elongation, Percent in 2"	Reduction of Area, Percent	Impact, ft./lbs.
1	C	56,780	43,865	37.0	67.9	135
7	C-Mo	60,795	41,780	35.3	70.1	139
2	Mo-Co	59,670	40,030	36.5	70.5	76
5	Mo-Ti	67,050	49,200	31.8	75.5	80
3	Mo-Co-Ti	65,795	47,350	33.3	77.8	186
4	Mo-Co-Ti	63,310	43,705	33.5	79.1	201
6	Mo-Co-Ti	61,950	41,650	35.2	74.3	218

Figures of the above table show that the impact strength of Mo-Co-Ti group of alloys is far superior to that of all other steels, while the tensile strength, yield point, elongation, and reduction of area may be considered as being within the generally similar ranges.

Creep-test results obtained on some of the above steels are given in the following Table B.

Table B

Steel No.	Type	Stress for creep rate of 0.001%/hour at 1,000° F.	Stress for rupture in 1,000 hours at 1,000° F.
		lbs./in.²	*lbs./in.²*
1	C	5,000	9,200
7	C-Mo	11,000	23,000
2	Mo-Co	14,000	28,000
5	Mo-Ti	11,000	21,000
3	Mo-Co-Ti	11,000	23,000

It can be seen from this tabulation that molybdenum cobalt steel leads other alloys from the standpoint of creep properties, carbon steel is at the bottom of the list and the remaining alloys occupy an intermediate position.

Hardenability characteristics of these steels determined by quenching properly prepared specimens from 1700° F. according to the standard practice recommended by the American Society for Testing Materials (A 255–42T) are listed below in Table C, giving Rockwell C hardness as a function of the distance from the quenched end expressed in sixteenth of an inch.

Table C

Distance	Type of Steel						
	C (1)	C-Mo (7)	Mo-Co (2)	Mo-Ti (5)	Mo-Co-Ti (3)	Mo-Co-Ti (4)	Mo-Co-Ti (6)
1	24	35.5	29.5	18.5	12.5	5	18.5
2	22	31	27	17	11	------	18.5
4	17.5	27	23	14	7	------	16
6	13	24	19	12	4	------	12
8	8	19	15	9	------	------	9
10	4.5	16.5	12.5	6	------	------	7
12	------	14	10	------	------	------	4
14	------	12.5	8	------	------	------	2
16	5	11	6.5	------	------	------	------
18	------	10	------	------	------	------	------
20	------	8	------	------	------	------	------

An analysis of figures given in the above tabulation indicates that conventional carbon-molybdenum steel exhibits the greatest hardening characteristics and is followed by the molybdenum-cobalt steel, both of which are definitely more hardenable than the plain carbon steel having the same carbon content. Molybdenum-cobalt-titanium alloys show varying hardenability but in most cases this hardenability is substantially lower than of the other steels.

The above illustrative examples show that the steels of the present invention have a greater impact strength and resistance to hardening than the conventional steels used for pressure-vessel manufacture and accordingly such steels are better adapted for use in such vessels.

While I have shown and described several specific embodiments of my invention, it will be understood that these embodiments are merely for the purpose of illustration and description and that various other forms may be devised within the scope of my invention, as defined in the appended claim.

I claim:

A steel of the type designed for high temperature service having reduced hardenability and good impact properties after heating to above the upper critical temperature and rapidly cooling, said steel comprising .05 to .20% carbon, .15 to .50% manganese, .05 to .30% silicon, .40 to .60% molybdenum, .25 to .50% titanium, .25 to .60% cobalt, balance iron and residual impurities.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,053,346	Merten	Sept. 8, 1936

OTHER REFERENCES

Titanium in Steel, pages 195 to 197, edited by Comstock et al., published in 1945 by the Pitman Publishing Corporation, New York.