Patented May 25, 1954 2,679,454

UNITED STATES PATENT OFFICE

2,679,454

ARTICLE FOR LOW-TEMPERATURE USE

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No Drawing. Application February 8, 1952, Serial No. 270,759

4 Claims. (Cl. 75—124)

1

This invention relates to wrought steel articles having superior impact resistance at temperatures below 0° C.

Most steels when cooled below room temperatures become less resistant to shock or impact. The resistance to impact does not ordinarily decrease proportionally with the temperature but decreases precipitously when the steel is cooled below a critical temperature which is referred to as the transition temperature. Machine parts and structural members subjected to impact at low temperatures must be made of steel having a transition temperature lower than their operating temperatures or else compensations must be made in the design of such articles to provide for their greatly diminished resistance to impact.

It is an object of the invention to provide articles for use at sub-zero temperatures which have an increased resistance to impact.

Another object of the invention is to lower the transition temperature of certain steels and thus render articles made from such steels more useful for jobs in which the articles are subjected to impact at low temperatures.

Efforts in the past to improve the low temperature properties of steels have resulted in the discovery that the addition of aluminum to certain steels has a beneficial effect. For example, the addition of aluminum to chromium-nickel-copper steels has been taught for the purpose of lowering the transition temperature of these steels. The present invention is based on the discovery that articles having superior low temperature properties can be fabricated from chromium-nickel-copper steels to which have been added specified percentages of both aluminum and nitrogen. The steels thus obtained have greater resistance to impact and lower transition temperatures than those steels to which aluminum alone is added despite the fact that nitrogen is taught by the art to be an embrittling agent.

The objects of the invention are accomplished by fabricating articles from steel having the following composition: carbon not to exceed 0.25%, not over 2% manganese, not over 1% silicon, 0.25% to 1.25% copper, not over 5% nickel, 0.25% to 3.25% chromium, 0.08% to 0.3% aluminum, 0.013% to 0.03% nitrogen, balance substantially all iron.

A preferred composition falls within the following range: 0.01% to 0.2% carbon, 0.2% to 1% manganese, 0.02% to 0.8% silicon, 0.25% to 1.25% copper, 0.5% to 3% nickel, 0.5% to 1.5% chromium, 0.08% to 0.3% aluminum, 0.013% to 0.03% nitrogen balance substantially all iron.

2

Steels manufactured by conventional methods have a nitrogen content of about 0.007%. The advantages of this invention are not obtained unless the nitrogen content of the steel is above at least 0.013% and unless this higher than normal nitrogen content is coupled with a soluble aluminum content of at least 0.08%. Any proportions of the two materials within the ranges 0.013% to 0.03% for nitrogen and 0.08% to 0.3% for aluminum will impart to the steel from which the articles of the invention are fabricated an improved resistance to impact at low temperatures. It is of interest to note that while a nitrogen content of 0.03% is within the preferred limits of the invention, a nitrogen content of no more than about 0.02% is required to obtain most of the improvements in the low temperature properties of the steel.

Table I sets forth data showing the improvements accomplished by the invention. The tests were conducted on a Charpy machine using standard keyhole specimens. The compositions of the specimens were substantially all iron plus the elements listed in the table. The specimens were cooled by immersion in a petroleum-ether which was cooled by liquid oxygen or nitrogen. After immersion in the cooling fluid for one hour, the test specimens were quickly transferred to a Charpy machine and the hammer of the machine released immediately.

Most of the specimens tested and reported in Table I exhibited a precipitous decrease in resistance to impact when cooled below a certain temperature. The impact resistance of other specimens decreased more gradually within the temperature range used in the tests. For purposes of comparison, an impact value of 15 foot-pounds, representative of a significant value, was chosen as the reference point. The temperature at which a steel exhibits an impact strength of 15 foot-pounds is designated the transition temperature in the table.

The proportions of the elements in the steel were varied from one specimen to another to establish more clearly the effect of the combination of nitrogen and aluminum, within the specified limits, on the impact strength of the steel. For convenience in making comparisons, the tests results are grouped so that within any group one element in addition to the aluminum and nitrogen is the principal variant. No nitrogen was added intentionally to those alloys containing 0.007% nitrogen, this being the normal nitrogen content of the steels made by conventional methods.

The specimens were also given several different heat treatments. The values appearing in column I of Table I are those obtained with specimens normalized at 925° C. The values in column II are those for specimens normalized at 925° C. and stress relieved at 593° C. The values in column III are those for specimens normalized at 925° C. and stress relieved at 650° C.

The steels from which articles of the invention are fabricated have a normal crystal structure and require no special treatment during fabrication. Welded pressure vessels fabricated from steels according to the invention give excellent service when subjected to low temperatures during use. Conventional fabricating techniques, such as welding, forging, and rolling, can be employed in making the articles of the invention.

Table I

Element Varied	Chemical Composition—Per Cent								Charpy Keyhole Impact Strength (Ft.-lb. per Sq. Cm.)									
									I				II			III		
									Test Temp., ° C.			Transition Temp., ° C.	Test Temp., ° C.		Transition Temp., ° C.	Test Temp., ° C.		Transition Temp., ° C.
	C	Mn	Si	Cu	Ni	Cr	Al	N	−160	−183	−196		−160	−183		−160	−183	
Carbon	0.045	0.23	0.11	0.51	1.45	0.92	0.18	0.007	46.0	5.0	----	−170	13.5	4.1	Above −160	5.7	3.0	Above −160.
	0.052	0.27	0.13	0.51	1.48	0.98	0.16	0.018	55.0	8.0	----	−170	52.0	5.2	−170	49.5	3.8	−170.
	0.14	0.52	0.26	0.44	1.44	1.01	0.15	0.007	32.8	3.6	----	−170	----	5.4	----	----	7.1	
	0.17	0.50	0.27	0.53	1.47	1.00	0.15	0.018	26.2	11.8	----	−170	----	5.5	----	----	9.0	
Manganese	0.045	0.27	0.12	1.06	1.45	0.97	0.15	0.007	48.0	6.3	----	−170	5.8	4.0	Above −160	6.5	2.8	Above −160.
	0.047	0.28	0.17	1.01	1.50	1.00	0.17	0.018	----	43.0	41.8	Below −196	4.7	4.2	Above −160	38.5	3.4	−170.
	0.047	0.78	0.19	1.08	1.43	1.01	0.26	0.018	20.0	7.0	----	−170	18.2	4.2	−170	----	----	
Silicon	0.048	0.29	0.15	0.53	1.96	1.00	0.26	0.007	33.5	4.2	----	−170	34.5	5.1	−170	5.0	3.4	Above −160.
	0.046	0.22	0.11	0.51	1.50	0.91	0.17	0.016	----	76.0	4.2	−190	55.5	8.8	−170	70.0	5.3	−170.
	0.085	0.42	0.29	0.93	1.40	0.71	0.09	0.015	----	23.0	----	Below −183	----	19.0	Below −183	----	----	
Copper	0.048	0.29	0.15	0.53	1.96	1.00	0.26	0.007	33.5	4.2	----	−170	34.5	5.1	−170	5.0	3.4	Above −160.
	0.046	0.22	0.11	0.51	1.50	0.91	0.17	0.016	----	76.0	4.2	−190	55.5	8.8	−170	70.0	5.3	−170.
	0.045	0.27	0.12	1.06	1.45	0.97	0.15	0.007	48.0	6.3	----	−170	5.8	4.0	Above −160	6.5	2.8	Above −160.
	0.038	0.30	0.09	1.09	1.44	0.96	0.23	0.021	48.5	31.0	----	Below −183	17.5	3.0	−170	----	----	
Nickel	0.045	0.27	0.12	1.06	1.45	0.97	0.15	0.007	48.0	6.3	----	−170	5.8	4.0	Above −160	6.5	2.8	Above −160.
	0.038	0.30	0.09	1.09	1.44	0.96	0.23	0.021	48.5	31.0	----	Below −183	17.5	3.0	−170	----	----	
	0.075	0.44	0.31	0.50	2.63	0.77	0.21	0.007	16.0	3.4	----	−160	----	----	----	----	----	
	0.032	0.26	0.13	0.50	2.16	1.00	0.13	0.021	90.0	5.5	----	−170	84.0	56.0	Below −183	----	----	
Chromium	0.088	0.48	0.33	0.50	1.51	0.76	0.20	0.007	54.0	11.4	----	−170	----	----	----	----	----	
	0.085	0.42	0.29	0.93	1.40	0.71	0.09	0.015	----	23.0	----	Below −183	----	24.3	−183	----	----	
	0.14	0.52	0.26	0.44	1.44	1.01	0.15	0.007	32.8	3.6	----	−170	----	5.4	----	----	----	
	0.13	0.42	0.23	0.55	1.60	1.05	0.16	0.019	----	16.0	4.0	−190	40.0	10.0	−175	----	----	
Aluminum	0.088	0.48	0.33	0.50	1.51	0.76	0.20	0.007	54.0	11.4	----	−170	----	----	----	----	----	
	0.085	0.42	0.29	0.93	1.40	0.71	0.09	0.015	----	23.0	----	Below −183	----	24.3	−183	----	----	
	0.094	0.54	0.25	0.53	1.60	0.87	0.26	0.007	[1] 9.7	5.0	----	Above −150	----	----	----	----	----	
	0.10	0.59	0.27	0.52	1.55	0.78	0.23	0.018	31.2	9.0	----	−170	----	----	----	----	----	

[1] Test temp., −150° C.

Carbon is the principal element, besides nitrogen, that is varied in four of the specimens tested. The data obtained from the testing of these specimens are recorded on successive lines in the table. These data indicate that those specimens having a high nitrogen content of 0.018% and an aluminum content above the specified minimum of 0.08% are generally more resistant to impact and have lower transition temperatures than those specimens having a normal nitrogen content of 0.007%. This relationship holds true whether the carbon content of the specimen is in the relatively low range of 0.045% to 0.052% or in the higher range of 0.14% to 0.17%.

In the other groups of specimens in the table either manganese, silicon, copper, nickel, chromium, or aluminum is the principal element varied besides nitrogen. The data for these groups show results similar to those for the group in which carbon and nitrogen are the principal elements varied. In each group, those specimens having a nitrogen and aluminum content within the specified limits exhibited improved low temperature impact resistance. The presence of a high aluminum content in a specimen does not impart to that specimen the advantages of the invention. In this respect the last group in the table in which aluminum and nitrogen are the principal elements varied is of interest. Those specimens having both a high nitrogen and aluminum content within the limits of the invention exhibited a substantially lower transition temperature than those specimens having a nitrogen content lower than 0.013% and thus outside the limits of the invention.

What is claimed is:

1. An article required to resist impact at temperatures below 0° C., said article being composed of a wrought steel having a composition comprising carbon in an amount not to exceed 0.25%, not over 2% manganese, not over 1% silicon, 0.25% to 1.25% copper, not over 5% nickel, 0.25% to 3.25% chromium, 0.08% to 0.3% aluminum, 0.013% to 0.03% nitrogen, the remainder iron and incidental impurities, and said steel having a transition temperature not higher than −170° C.

2. An article required to resist impact at temperatures below 0° C., said articles being composed of a wrought steel having a composition comprising 0.01% to 0.2% carbon, 0.2% to 1% manganese, 0.02% to 0.8% silicon, 0.25% to 1.25% copper, 0.5% to 3% nickel, 0.5% to 1.5% chromium, 0.08% to 0.3% aluminum, 0.013% to 0.03% nitrogen, the remainder iron and incidental impurities, and said steel having a transition temperature not higher than −170° C.

3. A welded pressure vessel for use at temperatures below 0° C., said welded pressure vessel being composed of a wrought steel having a composition comprising carbon in an amount not to exceed 0.25%, not over 2% manganese, not over 1% silicon, 0.25% to 1.25% copper, not over 5% nickel, 0.25% to 3.25% chromium, 0.08% to 0.3% aluminum, 0.013% to 0.03% nitrogen, the remainder iron and incidental impurities, and said steel having a transition temperature not higher than −170° C.

4. A welded pressure vessel for use at tem-

peratures below 0° C., said welded pressure vessel being composed of a wrought steel having a composition comprising 0.01% to 0.2% carbon, 0.2% to 1% manganese, 0.02% to 0.8% silicon, 0.25% to 1.25% copper, 0.5% to 3% nickel, 0.5% to 1.5% chromium, 0.08% to 0.3% aluminum, 0.013% to 0.03% nitrogen, the remainder iron and incidental impurities, and said steel having a transition temperature not higher than −170° C.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,229,140	Smith	Jan. 21, 1941

OTHER REFERENCES

Transactions, American Institute of Mining and Metallurgical Engineers, vol. 125, page 570. Published in 1937 by the A. I. M. E., New York.

Mechanical Properties of Metals at Low Temperatures, pages 50 to 55. Published in 1952 by the U. S. Government Printing Office, Washington, D. C.