Patented Jan. 21, 1941

2,229,140

UNITED STATES PATENT OFFICE

2,229,140

ABNORMAL STEEL

Earle C. Smith, Cleveland Heights, and George T. Motok, Massillon, Ohio, assignors to Republic Steel Corporation, Cleveland, Ohio, a corporation of New Jersey

No Drawing. Application December 20, 1939, Serial No. 310,175

4 Claims. (Cl. 75—124)

This invention relates to the art of steel making. It is particularly concerned with new and improved steels which are consistently abnormal and fine grained and can be made in open hearth furnaces.

Since about 1922 steels have been classified as "normal" or "abnormal," depending upon the extent to which the grains are surrounded by the grain boundary material, i. e., cementite. When the grain boundary material is well defined and substantially continuous around each grain the steel is said to be normal, but when the grain boundary material is not substantially continuous the steel is said to be abnormal, and the degree of abnormality depends upon the extent to which the boundary material is interrupted. A steel is classified in the trade as normal or grade A steel when it has a substantially continuous boundary of cementite around each grain. Abnormal steels are classified in the trade (Dodge test) in grades B, C and D. In grade B the boundary material is slightly broken; in grade C it is considerably broken; and in grade D it is more or less limited to one or possibly two sides of the grain and has an appearance which is often referred to as "grape bunches."

For approximately the same length of time the steel industry has classified the sizes of grains in steel according to the standard chart of the American Society for Testing Materials. This chart extends from number 1 for very coarse grains to number 8 for very fine grains.

The present invention has to do particularly with abnormal steels which are classifiable in grades B, C or D (Dodge test), which have grains ranging in size between about #5 and about #8 on the A. S. T. M. standard scale, and which have compositions within the following ranges:

	General range	Preferred range
	Percent	*Percent*
Iron	99.27 to 90.44	98.96 to 94.37
Carbon	.15 to 2.0	.15 to 1.25
Manganese	.30 to 3.0	.50 to 1.5
Molybdenum	.20 to 1.5	.20 to .70
Silicon	.15 to 2.5	.15 to 2.0
Sulphur	.01 to .4	.02 to .06
Phosphorus	.01 to .05	.01 to .04
Aluminum	.003 to .05	.003 to .05
Nitrogen	.007 to .03	.007 to .018
Oxygen	.0005 to .03	.0005 to .03

Elements which have a retarding effect on the solubility of carbides, such as titanium, vanadium, zirconium and columbium, may be incorporated in the foregoing compositions and when any one of such elements is present in proper amounts the nitrogen content may be as low as about .004% without any material variation in properties of the steel as compared with those where that element is absent and the nitrogen is not lower than about .007%. When titanium is thus employed it should range between about .01% and about .35% with the preferred amount being about .02%. When vanadium is employed it should range between about .01% and about .5% with the preferred amount being about .02%. When zirconium is employed it should range between .01% and .04% with the preferred amount being about .01%. When columbium is employed it should range between about .01% and about .30% with the preferred amount being about .05%.

The patent to Wills, No. 1,992,905 issued February 26, 1935, discloses a steel containing several elements, some of which fall within the foregoing ranges, and describes a process for making the disclosed steel. According to that process, small amounts of aluminum are added to the thoroughly deoxidized steel composition and steps are taken to insure that all the aluminum will be converted into alumina and that the alumina will be well dispersed.

For several years after the Wills invention, applicants tried to make the steel of that patent by the process disclosed therein but found that the steel could not be made consistently in an open hearth furnace and hence electric furnaces were used almost exclusively. Frequently even an electric furnace heat would be unsatisfactory without any apparent reason. This was the case even when part of the charge for the heat was metal from a similar previous heat. It was never possible to predict that any particular heat would be satisfactory and, since the reason why some heats were unsatisfactory was unknown, it was not possible to control the heats so as to avoid the making of unsatisfactory heats.

It was particularly difficult to produce an abnormal steel of the Wills composition with a grain size between Nos. 5 and 8 and sometimes, without any apparent reason, the grains grew as large as 1. At other times the grains in the surface portions of the steel article would be within the permissible size range but the core grains would be greatly coarsened. Since the steel was unsatisfactory if either the surface or core grains were too large, many heats were rejected because of unsuitable grain size.

Many efforts were made to determine the causes of these unsatisfactory heats and to prevent the making of such heats, but, so far as we know, no entirely successful solution of the problem was made prior to the present invention.

This invention enables us to make steels of the Wills type with full assurance that each and every heat will be satisfactory insofar as the degree of abnormality and size of grains in surface and core portions are concerned. While the present invention makes it possible to control heats made in electric furnaces and insure consistently satisfactory results, it makes the use of electric furnaces unnecessary for open hearth furnaces can be used, and are now being used commercially, to make these steels.

In addition to these outstanding accomplishments of the invention as regards the method and its control, the present invention enables us to make steels which are of the type disclosed in the Wills patent but which possess new, improved and valuable properties not possessed by the steels of that patent.

The method of the present invention may be practiced on an open hearth steel as follows: A heat of molten steel intended for the above compositions is made in the usual manner in an open hearth furnace. While still in the furnace, it is partially deoxidized with Mn, Si and Al and the deoxidation is completed in the ladle or molds. When such molten steel is in a partially, but preferably incompletely, deoxidized condition, it is treated with additional aluminum and a nitrogen containing compound which is capable of liberating nascent nitrogen in the molten metal. About 70% of this aluminum goes into solution in the molten metal and remains therein as metallic aluminum, thus constituting between about .02% and about .05% of the steel. The remaining 30% apparently forms non-metallic materials such as oxides, sulphides and the like.

The nitrogen bearing material is preferably added to the metal in the ladle but it may be added when the metal is being poured into the molds or even while the metal is still in the furnace. Calcium cyanamid is an example of a nitrogen bearing material which is suitable for the purposes of the present invention. From about 2 pound to about 5 pounds of calcium cyanamid per ton of molten metal has been found to be sufficient. When this amount of calcium cyanamid is used, the resulting steel contains between about .007% and about .012% of nitrogen.

We do not thoroughly understand the reasons why the method of the present invention produces consistently satisfactory heats with this type of steel even in an open hearth furnace, as has been our experience over a long period of time in commercial production of such steel. However, we believe that these results are traceable to the fact that the steel contains increased amounts of nitrogen and decreased amounts of oxygen.

The steels of the present invention are characterized by being abnormal within grade B, C or D, having grain sizes between numbers 5 and 8 on the standard scale with core grains which are not materially coarsened, having a high degree of ductility and toughness and resistance to shock and fatigue and having an increased rolling temperature range, all as compared with the steels of the Wills patent.

The following table gives differences in certain properties between the steel of the Wills patent and the corresponding steel of the present invention:

	Wills O. H. fce steel (0.3% C.)	Present O. H. steel (0.3% C.)
T. S. lbs./sq. in	94,770	97,690
El. limit lbs./sq. in	42,650	45,260
Percent elon	27.3	28.7
Percent red. of area	56.4	57.7
Brinell hardness	179	197
Nitrogen .... percent	.0035-.0042	.0060-.0168
Oxygen .... do	.0048-.0068	.00212
Izod impact:		
1½ hrs. at 1,700° F	160	254
8 hrs. at 1,700° F	140	250

The physical properties set out in the middle column of the foregoing tabulation were present in a heat of steel made strictly according to regular open hearth practice and the procedure outlined in the Wills patent. About 1.2 pounds of aluminum per ton of steel was added to this heat, part being added to the bath and part to the ladle. The oxygen and nitrogen contents specified in the same column were the ranges of these ingredients found from analysis of a number of similarly made heats of like steel. In one of those heats the nitrogen content was .004%. In one ingot of that heat to which 1¼ pounds of calcium cyanamid per ton of steel had been added, the nitrogen content was .007% while in another ingot of the heat to which about 2½ pounds of calcium cyanamid per ton of steel was added the nitrogen content was .010%.

The physical properties set forth in the righthand column of the above tabulation were present in a heat of steel made in exactly the same way as the heat represented by the middle column in the tabulation, except that about 2 pounds of aluminum per ton of steel was added to the metal, part being added to the bath and part to the ladle, and 2½ pounds of calcium cyanamid per ton of steel were added to the ladle. The nitrogen contents specified in the righthand column of the above tabulation were the results of analyses of a number of similar heats while the oxygen content specified in the same column was substantially that found in each of such heats.

The foregoing tabulation and explanation thereof indicates the new and unexpected results obtained when steels of the Wills type are made in the regular way specified in the Wills patent, but with the use of an additional amount of aluminum to insure the presence of aluminum in solution in the final steel and the addition of small amounts of calcium cyanamid.

Having thus described the invention so that others skilled in the art may be able to practice the same, we state that what we desire to secure by Letters Patent is defined in what is claimed.

What is claimed is:

1. An alloy steel having an abnormality of at least grade B (Dodge test) and a grain size in the outer portions not larger than about #5 on the A. S. T. M. scale and containing carbon from about .15% to about 2.0%, manganese from about .30% to about 3.00%, silicon from about .15% to about 2.50%, molybdenum from about .20% to about 1.5%, nitrogen from about .007% to about .03%, aluminum from about .003% to about .05% and oxygen between about .0005% and about .03%, the remainder being substantially all iron with small amounts of sulphur and phosphorus.

2. An alloy steel having an abnormality of at least grade B (Dodge test) and a grain size in the outer portions thereof not larger than #5 on

the A. S. T. M. scale, and containing carbon from about .15% to about 2.0%, manganese from about .30% to about 3.00%, silicon from about .15% to about 2.50%, molybdenum from about .20% to about 1.50%, nitrogen from about .004% to about .03%, aluminum from about .003% to about .05%, oxygen from about .001% to about .003%, and an element of the group consisting of titanium, vanadium, zirconium and columbium, having a retarding effect on the solubility of carbides, in the following amounts, titanium from .01% to about .35%, vanadium from .01% to about .5%, zirconium from .10% to about .04% and columbium from .01% to about .3%, the remainder being substantially all iron with small amounts of sulphur and phosphorus.

3. An alloy steel having an abnormality of at least grade B (Dodge test) and a grain size in the outer portions not larger than about #5 (A. S. T. M. scale) and containing carbon from about .15% to about 1.25%, manganese from about .50% to about 1.50%, molybdenum from about .20% to about .70%, silicon from about .15% to about 2.0%, aluminum from about .003% to about .05%, nitrogen from about .007% to about .018% and oxygen from about .0005% to about .03%, the remainder being substantially all iron with small amounts of sulphur and phosphorus.

4. An alloy steel having an abnormality of at least grade B (Dodge test) and a grain size in the outer portions not larger than about #5 (A. S. T. M. scale) and containing carbon from about .15% to about 1.25%, manganese from about .50% to about 1.50%, molybdenum from about .20% to about .70%, silicon from about .15% to about 2.0%, aluminum from about .003% to about .05%, nitrogen from about .004% to about .018%, oxygen from about .0005% to about .03%, and an element of the group consisting of titanium, vanadium, zirconium and columbium, having a retarding effect on the solubility of carbides, in the following amounts, titanium from .01% to about. 35%, vanadium from .01% to about .5%, zirconium from .10% to about .04% and columbium from .01 to about .3%, the remainder being substantially all iron with small amounts of sulphur and phosphorus.

EARLE C. SMITH.
GEORGE T. MOTOK.