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## ALLOY STEEL

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7 Claims. (Cl. 75—1)

My invention relates to chromium steels, referring more specifically to a means of improving such steels.

It is the object of my invention to improve the physical properties of alloy steels containing a high percentage of chromium, and I attain this object by applying my discovery that the addition of nitrogen in alloying quantities appreciably greater than those normally present in steels affects the physical properties of high-chromium steels favorably and to a marked degree.

It is a matter of common observation and experience that cast high-chromium steels consist of coarse crystals and grains loosely bound together. Castings of this metal are weak and actually porous, as shown by hydraulic tests at high pressure. This coarse structure in cast high-chromium steel is to a considerable extent responsible for the comparatively poor physical properties of the metal. A refinement of the grain-structure is greatly to be desired for the production of steels with superior physical properties.

I have found that the presence of nitrogen in amounts greater than about 0.2% materially improves the physical properties of wrought and cast steels which contain a large percentage of chromium. Although wrought chromium steels do not have the coarse grain-structure of the cast metal, the application of my invention produces marked improvements over the normally good structure of these steels. My invention is therefore applicable not only to cast, but also to wrought chromium steels, and produces a superior product in either case.

According to my invention, some benefit may be had by the use of a nitrogen content somewhat less than 0.2%, but it is preferable that the nitrogen content be at least this value. In general, it is desirable to have the maximum amount of nitrogen present that can be retained in stable combination at the temperatures which are required for casting the metal. The amount of nitrogen which can be retained in the final product increases with increased chromium content; thus, a steel containing about 15% chromium will retain up to approximately 0.2% nitrogen, while a steel containing about 35% chromium will retain up to approximately 0.65% nitrogen.

My invention is especially valuable when applied to steels containing from about 15% to 35% of chromium, although it is of beneficial effect when applied to steels of somewhat lower or higher chromium content. The presence of other alloyed constituents in the steel, such as nickel, in no way limits or decreases the benefits to be derived from the use of nitrogen. This invention is therefore applicable to high chromium steels generally.

Experiments which I have made demonstrate that the addition of nitrogen in amounts appreciably greater than those normally present in steels refines the grain-structure and improves the strength of high chromium steels without materially affecting their ductility, machinability, hardness, corrosion resistance, or forging, rolling and working characteristics. For instance, my tests show that the addition of about 0.2% to about 0.4% of alloyed nitrogen to wrought and cast chromium steels containing from about 18% to about 30% chromium and up to about 2% carbon greatly improves the physical properties of these steels. The beneficial effect of the added nitrogen is most marked in those steels containing less than about 1% of carbon, but continues to be appreciable when the carbon is raised as high as about 2%.

In one series of experiments a number of wrought steel test samples were made, each sample comprising a preponderance of iron, about 0.1% of carbon, about 0.4% manganese, about 0.5% silicon, a low percentage of impurities, and added chromium and nitrogen. The nitrogen was introduced into the molten steels in the form of chromium nitride and a high nitrogen ferro-chrome alloy. For each high-nitrogen sample so made there was prepared a corresponding low nitrogen steel having approximately the same composition in respect to every constituent except nitrogen. All of the samples were then subjected to a number of physical tests under comparable conditions. The effect of nitrogen as indicated by these tests is most conveniently shown by means of the following table:

| Analysis | | | | Physical properties | | | |
|---|---|---|---|---|---|---|---|
| % Cr | % N | Y. P. | T. S. | El. % | R. A. % | Eric. | Brinell |
| 19 | 0.04 | 46 | 77 | 30 | 60 | 7.5 | 131 |
| 19 | 0.28 | 56 | 100 | 26 | 56 | 6.5 | 170 |
| 23 | 0.03 | 47 | 68 | 31 | 52 | 7.5 | 128 |
| 23 | 0.37 | 51 | 89 | 26 | 57 | 8.0 | 149 |
| 26 | 0.03 | 50 | 77 | 27 | 59 | 7.5 | 128 |
| 26 | 0.42 | 50 | 83 | 24 | 46 | 8.0 | 128 |

In the above table of wrought steels, the following symbols are used: Y. P. for yield point in

thousands of pounds per square inch, T. S. for tensile strength in thousands of pounds per square inch, El. % for percentage elongation obtainable in 2 inches, R. A. % for percentage reduction in area of cross section accompanying the elongation, Eric. for the values obtained using the Erichsen machine, and Brinell for the hardness values on the Brinell scale.

A microscopic examination of the wrought steels showed that nitrogen greatly refines the structure of the metal and appears to eliminate the grain boundaries of the crystals. Further testing of the steels demonstrated that the addition of nitrogen decreases their tendency to become embrittled at elevated temperatures, such as those of the order of 475° C.

A corresponding series of tests were made on cast high chromium steels. A series of castings containing a preponderance of iron, a low percentage of impurities, about 15% to 35% chromium, about 0.5% of carbon, and with high and low nitrogen contents, were cast in the form of standard arbitration bars and tested. Nitrogen was found to improve the physical properties and refine the grain-structure greatly. A typical set of values obtained from this series of tests follows:

| Analysis | | Physical properties | | |
|---|---|---|---|---|
| % Cr | % N | Defl. | T.B.L. | Brinell |
| 25 | 0.10 | 0.14 | 4.6 | 187 |
| 25 | 0.35 | 0.33 | 7.0 | 207 |

In the above table for cast steels, the following symbols are used: Defl. for deflection in inches, T. B. L. for transverse breaking load in thousands of pounds, and Brinell for the hardness values on the Brinell scale.

The presence of nitrogen in no way decreases the resistance of chromium steels to staining and certain types of corrosion, as I have determined by extensive tests of both wrought and cast steels.

In making all castings used in my tests, I have followed a new and special procedure which I have developed for applying my invention. A low carbon steel, according to my procedure, is melted in one of the usual types of furnaces. During the melting process the desired amount of nitrogen is introduced into the molten metal as chromium nitride or a high nitrogen ferrochrome alloy or other suitable nitride or mixture of nitrides. After the steel is melted it is held at a temperature sufficiently above the melting point to allow the nitrogen liberated from the unstable nitrides to escape. By regulating the temperature of the molten steel, the content of the combined stable nitrides can be controlled to give solid cast metal, as the stability of the nitrides decreases with a rise in temperature. This method of producing high nitrogen steels avoids the formation of blowholes and excessive piping, since the nitrogen remaining in the steel is in an alloyed condition.

Although I have described a number of specific examples and disclosed the preferred form of my invention, it will be understood that these are merely representative embodiments, and do not tend to limit the scope of my real discovery and invention relative to a method generally applicable to the improvement of alloy steels containing a high content of chromium. I wish therefore to be limited only by the prior art and the appended claims.

I claim:

1. An alloy steel comprising a preponderance of iron, about 15% to 35% chromium, about 0.10% to 2% carbon, and nitrogen in an amount not less than about 0.2% and not greater than about 0.65%, and the balance chiefly iron; said steel having throughout substantially the same concentration of nitrogen.

2. An alloy steel comprising a preponderance of iron, about 18% to 30% chromium, about 0.10% to 2% carbon, and nitrogen in an amount not less than about 0.2% and not greater than about 0.65%, and the balance chiefly iron; said steel having throughout substantially the same concentration of nitrogen.

3. An alloy steel comprising a preponderance of iron, from about 18% to about 30% chromium, from about 0.10% to about 1% carbon, and from about 0.2% to about 0.4% nitrogen, the balance chiefly iron; said steel having throughout substantially the same concentration of nitrogen.

4. Alloy steel comprising from about 18% to about 30% of chromium, from about 0.10% to about 1% of carbon, from about 0.2% to about 0.4% of combined nitrogen, and the balance substantially iron; said steel having throughout substantially the same concentration of nitrogen.

5. Fine-grained high-chromium iron-base alloy casting resistant to staining, corrosion and high-temperature embrittling, and having approximately the composition: 15% to 35% of chromium, 0.10% to 2% of carbon, 0.20% to 0.40% of combined nitrogen, and the balance substantially iron; said casting having throughout substantially the same concentration of nitrogen.

6. An alloy steel consisting of about 15% to 35% chromium, about 0.10% to 1% carbon, about 0.2% to 0.65% nitrogen, and the balance substantially all iron; said steel having throughout substantially the same concentration of nitrogen.

7. A ferrous alloy comprising about 18% to 30% chromium, 0.10% to 0.3% carbon, 0.2% to 0.5% nitrogen, and the balance substantially all iron; said alloy having throughout substantially the same concentration of nitrogen.

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