United States Patent Office 3,600,158
Patented Aug. 17, 1971

3,600,158

HOT-WORKABLE STEEL WITH SULFUR AND VANADIUM

Louis Molnar, Hammond, Ind., and William E. Heitmann, Dolton, Ill., assignors to Inland Steel Company, Chicago, Ill.

No Drawing. Filed July 13, 1967, Ser. No. 653,039
Int. Cl. C22c 39/50
U.S. Cl. 75—123 4 Claims

ABSTRACT OF THE DISCLOSURE

Plain carbon or alloy steel, having sulfur in residual or resulfurized amounts and containing at least 0.01 wt. percent but less than 0.03 wt. percent vanadium, columbium, tantalum or combinations thereof as grain refiner. Austenitic grain size at least as fine as 7 on ASTM scale. Sulfur-containing inclusions also contain oxygen, iron and manganese, have a globular shape and are randomly dispersed throughout microstructure. No aluminum.

BACKGROUND OF THE INVENTION

Sulfur is present in steel either in residual amounts or in larger amounts purposely added to impart desired properties (such as improved machinability) to the steel.

Sulfur is generally found in steel as a component of a microscopic inclusion also containing iron, manganese and oxygen. These sulfur-containing inclusions are in the absence of some interfering medium, generally globular in shape and are randomly dispersed throughout the microstructure of the steel.

It is desirable for steel to have a relatively fine austenitic grain size because this improves the toughness of the steel. A common practice for refining the grain size of steel is to add a grain refiner; and a common grain refiner has been aluminum, e.g., in amounts between 0.02 and 0.05 wt. percent.

Aluminum is also a deoxidizer and, when added as a grain refiner, substantially reduces the amount of oxygen in the steel. For example, in a steel otherwise normally having 150–200 parts of oxygen per million parts of iron, grain refining with 0.02–0.05 wt. percent aluminum reduces the oxygen content to less than 50 parts per million parts of iron.

When aluminum deoxidizes the steel, it substantially eliminates oxygen as a component of the sulfur-containing inclusion; and, when this occurs, the shape and distribution of the inclusions change from a globular shape randomly dispersed throughout the microstructure to a stringy shape concentrated at the grain boundaries of the microstructure.

When a steel has sulfur-containing inclusions concentrated at the grain boundaries of the steel, the hot-working characteristics of the steel are poorer than those of a steel having sulfur-containing inclusions randomly dispersed throughout the microstructure.

When a steel has sulfur-containing inclusions with a stringy shape, the machinability of the steel is poorer than that of steel having sulfur-containing inclusions which are globular in shape.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a steel having a relatively fine austenitic grain size (at least as fine as 7 on the ASTM scale) together with sulfur-containing inclusions having oxygen as a component. The inclusions are randomly dispersed throughout the microstructure of the steel and have a globular shape.

The steel contains a grain refiner selected from the group consisting of columbium, tantalum, vanadium and

combinations thereof, in an amount at least 0.01 wt. percent and less than 0.03 wt. percent. Aluminum is not used as a grain refiner and no aluminum is present in the steel.

Columbium, tantalum, vanadium, or combinations thereof, in the range specified in the preceding paragraph, effectively refine the grain size of the steel. Lesser amounts would have no significant effect on grain refinement; and additional amounts would have no significant additional effect on grain refinement, compared to an amount, such as 0.02 wt. percent, within the range specified. Because these elements are relatively expensive, it is important that they not be added in amounts at which no significant additional effect is produced.

Columbium, vanadium and tantalum are not deoxidizers so that oxygen is not removed from the steel by these grain refiners, and oxygen is present as a component of the sulfur-containing inclusion, along with iron and manganese. Thus, a steel normally containing 150–200 parts of oxygen per million parts of iron would have the same oxygen content both before and after the addition of a grain refiner in accordance with the present invention.

The invention is applicable to all sulfur-containing steels, whether the sulfur is present in residual amounts (e.g. 0.03–0.05 wt. percent) or is present in resulfurized amounts purposely added to impart desired properties to the steel. An example of the latter is sulfur added to improve the machinability of the steel, in which case sulfur is added in amounts typically between 0.1 wt. percent and 0.35 wt. percent. This invention is applicable to all types of sulfur-containing base steels, whether the base steel be a plain carbon steel or an alloy steel.

Other features and advantages are inherent in the steel claimed and disclosed or will become apparent to those skilled in the art from the following detailed description.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Illustrative examples of base steels which may be modified in accordance with the present invention are tabulated below. The examples include a plain carbon steel having residual amounts of sulfur (AISI 1040), a plain carbon, resulfurized steel (AISI 1117) and an alloy steel having residual sulfur (AISI 4142). The respective compositions of these base steels are as follows:

Element	AISI 1040	AISI 1117	AISI 4142
Carbon	0.37–0.44	0.14–0.20	0.40–0.45
Manganese	0.6–0.9	1.0–1.3	0.75–1.0
Phosphorous	[1] 0.04	[1] 0.04	[1] 0.04
Silicon	0.1–0.3	[1] 0.1	0.20–0.35
Sulfur	[1] 0.05	0.08–0.13	0.035–0.05
Chromium			0.8–1.1
Molybdenum			0.15–0.25

[1] Maximum.

Each of these base steels may be modified in accordance with the present invention by adding at least 0.01 wt. percent but less than 0.03 wt. percent vanadium, columbium, tantalum or combinations thereof.

For each of the compositions listed above, when modified in accordance with the present invention, aluminum is not added as a grain refiner and aluminum is not present in the steel. The steel has an austenitic grain size of 7 or finger on the ASTM scale, the austenitic grain size being determined by the conventional McQuaid-Ehn grain size test.

The sulfur-containing inclusions in these steels have a globular shape and are randomly dispersed throughout the microstructure of the steel. The sulfur-containing inclusions also include iron, manganese and oxygen.

In the AISI 1117 steel, sulfur has been added to improve the machinability thereof. The machinability of a steel may also be improved by including selenium and/or

tellurium in amounts between 0.02–0.10 wt. percent; and neither the machinability nor the hot-working characteristics of such a steel are adversely effected by using a grain refiner in accordance with the present invention, compared to the use of aluminum as a grain refiner.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:

1. In a steel having sulfur-containing inclusions:
at least 0.01 wt. percent and less than 0.03 wt. percent of a grain refiner selected from the group consisting of columbium, tantalum, vanadium and combinations thereof;
said grain refiner being present in an amount sufficient to produce an austenitic grain size in said steel at least as fine as 7 on the ASTM scale;
said steel being devoid of aluminum;
said sulfur-containing inclusions also containing oxygen;
said sulfur-containing inclusions having a globular shaped and being randomly dispersed throughout the steel.

2. In a steel as recited in claim 1 wherein the sulfur content is at least a residual amount and up to 0.35 wt. percent.

3. In a steel as recited in claim 2 wherein said sulfur content is at least 0.1 wt. percent.

4. In a steel as recited in claim 1 wherein said inclusions consist essentially of iron, manganese, sulfur and oxygen.

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CHARLES N. LOVELL, Primary Examiner