

## UNITED STATES PATENT OFFICE

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## ALLOY STEEL

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This invention relates to sulfur-bearing steels, more especially referring to improvements in such steels, and the immediate object of my invention is to produce a superior free-machining sulfur steel.

The presence of sulfur in amounts appreciably greater than those considered desirable in structural and engineering steels is known to be advantageous from the standpoint of ease of machining. Screw stock for example is customarily produced with a sulfur content of about 0.10%, as contrasted with the upper limit of about 0.050% usually specified for engineering steels. Despite their desirable machining characteristics however, the high sulfur steels are strictly limited in their application, for when made by methods heretofore known they are not suitable for general engineering uses. A superior free-machining high sulfur steel is not only of value in the present field of application, since it provides a uniform and reliable engineering material, but also extends that field to many other uses where its desirable machining characteristics lead to savings in fabrication and finishing costs.

I have discovered that a superior high sulfur steel may be produced by the alloyed addition of proper amounts of vanadium. According to the preferred embodiment of my invention, from about 0.05% to about 1% of vanadium is added to a steel containing from about 0.075% to about 0.5% of sulfur to produce steel of superior machining and physical properties. The presence of vanadium in these amounts improves the machining properties, improves the hot and cold working characteristics, and decreases the size and effects a more uniform distribution of the sulfide inclusions in the steel without decreasing the ductility or shock resistance, as is shown by physical tests and microscopic examination.

The addition of vanadium in amounts other than those within the preferred range are of some benefit to the properties of sulfur steels, but less than 0.05% has only a slight effect, while the use of more than about 0.5% is inadvisable chiefly because the added expense of the vanadium offsets the advantages to be gained by the use of a greater amount. Furthermore, although the addition of vanadium appears to benefit the sulfide distribution in all sulfur steels, the free-machining sulfur steels as a class come within the range of sulfur content given above, and therefore my invention is most profitably to be applied to steels within this range.

Tests which I have made demonstrate clearly the improvement effected by the addition of

vanadium. For example, typical high sulfur steels containing about 0.11% of sulfur, 1.2% of manganese and 0.15% of carbon were compared with similar steels containing as an alloyed addition from about 0.05% to about 0.35% of vanadium. It was found that the presence of vanadium effected a marked improvement in sulfide-inclusion size and distribution, and improved the machining characteristics remarkably. Further tests on these samples demonstrated that the addition of vanadium also improves the strength of sulfur steels without decreasing their ductility or shock resistance. The elastic limit is raised to about 75,000 or 90,000 pounds per square inch, and the ultimate strength to about 90,000 or 105,000 pounds per square inch.

As another typical example, I have found that a steel comprising about 0.125% of sulfur, about 0.30% of carbon, about 1.5% of chromium, alloyed additions of vanadium up to about 0.5%, and the remainder chiefly iron, has remarkably good machining properties in addition to excellent and valuable physical properties which render it valuable for engineering uses.

The steels of the present invention contain the small amounts of carbon, silicon, phosphorus, etc. usually contained as incidental impurities in free-machining sulphur steels.

Although I have described the preferred form of my invention, and have mentioned certain specific typical embodiments, it will be understood that my invention pertains to alloy sulfur steels generally.

I claim:—

1. An alloy steel characterized by properties of free-machinability and high strength, and which contains sulphur, vanadium, manganese, and carbon, the sulphur content being from about 0.075% to about 0.5%, the vanadium content being from about 0.05% to about 1.0%, the manganese content being not over about 1.25%, the carbon content being not over 0.5%, and the remainder, except for incidental impurities, being iron.

2. An alloy steel characterized by properties of free-machinability and high strength, and which contains sulphur, vanadium, manganese, and carbon, the sulphur content being from about 0.075% to about 0.5%, the vanadium content being from about 0.05% to about 0.50%, the manganese content being not over about 1.25%, the carbon content being not over 0.5%, and the remainder, except for incidental impurities, being iron.

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