

UNITED STATES PATENT OFFICE

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STEEL FOR HIGH-TEMPERATURE USE

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This invention relates to steels that combine desirable properties at normal temperatures with excellent high temperature properties.

Certain parts of jet engine and gas turbines, such as their rotors, and parts of aircraft superchargers and related devices operate at high stress and elevated temperatures. Various steels have been developed for such purposes, for instance the well-known steel alloy disclosed in United States Patent No. 2,398,702. In general, the steels used for such purposes up to the present time have been highly alloyed, and it is characteristic of them that they are either very difficult to fabricate or they require special heat treatments of long duration and, in some instances, are rather complicated.

The present shortage of certain critical metals has created the need for steels of low alloy content that are also adapted to replace the highly alloyed steels used up to the present time for the foregoing purposes. In particular, there is a demand for steels containing a maximum of 5 per cent of alloying elements and which possess a 1000-hour rupture strength at 1100° F. in excess of 30,000 pounds per square inch (p. s. i.). Steels meeting those requirements have not been available heretofore.

It is among the objects of the invention to provide low alloy steels having a satisfactory combination of high temperature properties, and particularly a rupture strength at 1000 hours and 1100° F. exceeding 30,000 pounds per square inch.

A further object is to provide steels in accordance with the foregoing object that likewise possess desirable physical properties at normal temperatures.

Still another object is to provide steels embodying the foregoing objects and whose properties are developed by a simple and short heat treatment.

Yet another object is to provide steels in accordance with the foregoing objects containing not over about 5 per cent of alloy content.

The invention is predicated upon my discovery that its stated objects are attained with steels containing from about 0.15 to 0.5 per cent of carbon, from about 0.75 to 2.5 per cent of chromium, from about 0.2 to 1.0 per cent of manganese, from about 0.25 to 1.0 per cent of molybdenum, from about 0.1 to 1.5 per cent of silicon and from about 0.2 to 1.0 per cent of vanadium. The remainder of the steels consists of iron together with impurities and elements in amounts that do not adversely affect the properties that characterize the steels of this invention. For full

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development of those properties the steels should not contain over about 0.04 per cent each of phosphorus and sulfur.

Within the foregoing limits I now prefer that the steels contain from about 0.18 to 0.28 per cent of carbon, from about 1 to 2 per cent of chromium, from about 0.3 to 0.6 per cent of manganese, from about 0.4 to 0.6 per cent of molybdenum, from about 0.5 to 1.0 per cent of silicon, and from about 0.7 to 0.9 per cent of vanadium.

Steels of the foregoing composition are readily fabricated by all hot forming operations such, for example, as forging, rolling, and piercing into seamless tubes. Likewise, they can be welded readily.

The best combination of strength and ductility at both room temperature and at 1100° F. is developed by air cooling, or normalizing, the steels from 1750° F. or higher, followed by tempering at about 1200° F. to about 300/350 Brinell. This heat treatment produces a martensitic structure.

The excellent properties of these steels and the high degree of shock resistance that they possess at elevated temperatures is characteristically exemplified by the properties of a steel in accordance with the invention and containing 0.22 per cent of carbon, 1.34 per cent of chromium, 0.55 per cent of manganese, 0.54 per cent of molybdenum, 0.6 per cent of silicon, 0.84 per cent of vanadium, 0.015 per cent of phosphorus and 0.023 per cent of sulfur. This steel when heat treated in the manner just described has the following room temperature properties:

35	Tensile strength	p. s. i.	139,500
	Proof stress	p. s. i.	102,250
	0.2% yield strength	p. s. i.	114,000
	Elongation in 2"	percent	17.5
	Reduction of area	do	64
40	Brinell hardness		321

In addition to a rupture strength after 1000 hours at 1100 F. of 33,000 p. s. i., this steel showed the following tensile properties at 1100° F.:

45	Tensile strength	p. s. i.	71,000
	Proportional limit	p. s. i.	32,500
	0.1% yield strength	p. s. i.	59,500
	0.2% yield strength	p. s. i.	64,000
	Elongation in 2"	percent	25
50	Reduction of area	do	69

Such properties adapt these steels for the making of parts that are subjected to high stress at such high temperatures as 1100° F., and obviously they represent a major saving of critical alloying elements in comparison with the pres-

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ently used alloy steels containing several times as much as alloy content as is present in these steels. The properties of these steels adapt them excellently for other purposes also, such as for aircraft brake discs.

According to the provisions of the patent statutes, I have explained the principle and mode of practicing my invention and have described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. A forgeable steel alloy which as normalized from 1750° F. and tempered at 1200° F. to a Brinell hardness of 300/350 is characterized by high strength at room and elevated temperatures and by a 1000 hour rupture strength at 1100° F. of at least 30,000 pounds per square inch and having substantially the composition: 0.18 to 0.28 per cent of carbon, 1 to 2 per cent of chromium, 0.3 to 0.6 per cent of manganese, 0.4 to 0.6 per cent of molybdenum, 0.5 to 1 per cent of silicon, and 0.7 to 0.9 per cent of vanadium, and the remainder iron together with impurities and elements in amounts that do not adversely affect the properties.

2. A hot worked and heat treated article formed of steel having substantially the composition: 0.18 to 0.28 per cent of carbon, 1 to 2 per cent of

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chromium, 0.3 to 0.6 per cent of manganese, 0.4 to 0.6 per cent of molybdenum, 0.5 to 1 per cent of silicon, and 0.7 to 0.9 per cent of vanadium, and the remainder iron, the article as normalized from 1750° F. and tempered at 1200° F. to a Brinell hardness number of 300/350 having high strength at room and elevated temperatures and a 1000 hour rupture strength at 1100° F. of at least 30,000 pounds per square inch.

3. Steel according to claim 1 containing not over about 0.04 per cent each of phosphorus and sulfur.

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