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HIGH-TEMPERATURE TURBINE

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My invention relates to high-temperature turbines, especially gas turbines, gas turbine parts, and related equipment.

Among the objects of my invention is the provision of tough, strong and reliable turbine parts, as for example wheels, rotors, blades or buckets, which are suitable for high-temperature duty and offer great strength and high resistance to corrosion in actual practical use where high temperature stresses in combination with the wash and scour of hot gases are encountered.

The invention consists in the turbine construction, especially the combination of elements, composition of ingredients and features of construction employed therein, all as described herein, the scope of the application of which is indicated in the following claims.

As conducive to a clearer understanding of certain features of my invention, it may be noted at this point that gas turbines are subjected to highly damaging high-temperature effects during operation. Many of the turbine parts, for example turbine blades, rotors, wheels, buckets, nozzles, and the like, are even directly exposed to the heating effects of the hot turbine-propelling gas. Under these high-temperature conditions the parts tend to warp, or fail for lack of strength and toughness. These deficiencies impose limitations on the life and efficiency of operation of the turbine.

In addition, under actual operating conditions, the interior of the turbine is directly contacted by the hot propelling gas. Direct scouring, and this usually either under oxidizing or reducing conditions, results. The parts consequently are inclined to pit and corrode so extensively as to diminish their effectiveness, or require replacement. The corrosive attack is accelerated by the severe temperature conditions under which certain of the parts function. The vibration encountered in use, as well as the stresses of operation, directly contribute to failure. In numerous instances the very nature of the metal employed makes the equipment susceptible to embrittlement, creep or fatiguing effects of high temperature, often coupled with corrosion or the formation of heat scale.

In way of further comment it may be said on the one hand, that the usual well-known carbon steels offer a variety of desirable properties at room temperature, but lose many of their valuable characteristics through exposure to the elevated temperatures encountered in turbine operation. A similar observation applies to numerous types of stainless steels. Although many of

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these alloys fall into the heat-resisting class, they still fall short of meeting the exacting requirements of turbine use. Known heat-resisting alloys of the high-temperature group, on the other hand, are notoriously difficult to work and therefore the production of wrought turbine equipment from the same presents no small problem, even on the assumption that the metal possesses the desired properties for eventual use as a finished product.

An outstanding object of my invention accordingly is the provision of turbine parts which are resistant to the wash and scour of turbine-propelling gases at elevated temperatures, and which are heat-resistant, mechanically strong, tough and durable under the peculiar conditions of use.

Referring now more particularly to the practice of my invention, I find that by properly selecting and correlating in a steel the ingredients chromium, nickel, molybdenum and copper with additions of manganese, columbium, and titanium, the carbon content being kept low, to give a fully austenitic steel, satisfactory hot-work properties are had. Such steel readily may be forged into the desired high-temperature turbine parts. Moreover, such parts as, for example, shafts, bolts, rivets, blades, buckets, wheels and rotors, and the like, possess desired operating characteristics. More specifically, I find that turbine parts containing 0.05% to 0.15% carbon, 12% to 22% chromium, 10% to 21% nickel, from 0.10% to 2.0% manganese, 2% to 4% molybdenum, copper ranging from 2% to 4%, from 0.15% to 0.75% titanium, 0.20% to 1.10% columbium, and the remainder substantially all iron possess excellent properties in use.

These parts are wholly austenitic in structure. Ferrite, if present at all, is only in traces. This I find essential to the required high stress-rupture properties. Where appreciable amounts of ferrite are present the stress-rupture values fall off. Also, as noted above, the working qualities of the metal suffer.

The composition limits given are considered to be in every sense critical since I find that where they are departed from one or more of the desired qualities suffer. For example, with a higher carbon content the working properties suffer and the parts are not so easily produced. To like effect with a manganese content exceeding 2.0% there is a loss in hot-working properties. With any appreciable lowering of the molybdenum and copper contents the desired high-temperature characteristics of the turbine suffer and with appreciable increase workability

disappears. The presence of both titanium and columbium in the amounts indicated is desirable because I find that in combination they improve the grain structure of the products and, in addition, contribute to the high stress-rupture values; where higher amounts of titanium and columbium are used, however, a loss of stress-rupture values occurs.

As a preferred embodiment of my invention, the gas-turbine parts consist of carbon 0.10% maximum, 17% chromium, 13% nickel, from 1.0% to 1.5% manganese, 3.0% molybdenum, 3.0% copper, 0.25% titanium, 0.40% columbium and the remainder substantially all iron. Incidental amounts of phosphorus, sulphur and silicon, of course, are present, the latter not exceeding 0.7% and the other two not exceeding 0.03%.

As illustrative of the practice of my invention austenitic chromium-nickel stainless steel first is produced, this for example in the form of ingots, in the manner described in Patent No. 1,925,182 of Alexander L. Field. These ingots are then re-heated and fashioned into billets by hot-rolling or forging from a temperature of about 2250° F. The billets then are forged into roughly formed shafts, bolts, wheels, buckets and the like. Machining to final size is achieved as desired. Fabrication of certain parts by welding with the oxy-acetylene torch, or electric arc means, employing welding rods preferably of approximately the same analysis as the stock being welded, is undertaken where desired.

As a matter of further preference, subsequent to the rough forging and then machining of my turbine parts, I age the same by heating at a temperature of say 1200° F. for about five hours. These are then air-cooled and pickled.

The turbine equipment which I provide is corrosion-resistant and heat-resistant. Moreover, it is capable of withstanding the exacting conditions of duty at temperatures up to about 1500° F. or more, over long periods of continuous use without grain growth, fatigue or failure. In use, the turbine parts display reliable strength in tension, compression and torsion. They are resistant to warping, and resist harmful scaling and attack by oxidizing or reducing gases.

In way of further illustration of properties, a sample of forged and aged metal (forged from 2250° F. and aged at 1200° F. for about five hours followed by air-cooling) taken from my turbine parts and analyzing approximately 0.097% carbon, 16.93% chromium, 13.10% nickel, 1.21% manganese, 2.98% copper, 2.95% molybdenum, 0.21% titanium, 0.43% columbium and the remainder substantially all iron, at the end of a 1000 hour tensile test at 35,000 p. s. i. at 1200° F. had a total extension of 0.60% in a 2-inch gauge length. This represents a rate of elongation of 0.000218% per hour. It therefore can be seen from the present example that the elevated temperature properties of my stainless steel articles and products are of an extremely high order with respect to resistance to elongation and creep.

I have exposed other samples of turbine steel of the composition noted to stress rupture tests at 1200° F. and found the same to endure a 49,000 pounds per square inch stress for 10 hours, and 43,000 p. s. i. for 100 hours, and 38,500 p. s. i. for 1000 hours.

Still other samples, these analyzing 0.090% carbon, 17.53% chromium, 13.18% nickel, 2.99% molybdenum, 2.99% copper, 0.42% columbium,

0.29% titanium, 1.21% manganese, and the remainder substantially all iron, were prepared and subjected to test with the following results:

Stress-rupture test at 1200° F.

[Condition A, annealed at 2050° F. for five hours and water quenched.]

Stress	Time
P. s. i.	Hours
48,000	10
40,250	100
34,500	1,000

[Condition B, annealed at 2250° F. for one-half hour and water quenched plus aging at 1200° F. for five hours and water quenched.]

Stress	Time
P. s. i.	Hours
60,000	10
48,000	100
38,500	1,000

Creep Tests

Condition	Test Temperature	Load	Initial Extension	Extension after 500 hrs.	Rate of Extension, per cent in 100,000 hrs. between 900th and 1800th hr.
	°F.	P. s. i.	Per cent	Per cent	
A-----	1,200	18,000	.105	.140	1.1
B-----	1,200	20,000	.145	.180	.88
B-----	1,350	10,000	.055	.140	1.07

My wrought austenitic chromium-nickel stainless steel turbine parts are capable of production in a simple, direct and economical manner by virtue of the comparative ease of working the particular metal employed, despite the high-temperature properties of the same, as by means of hot-forming operations and fabrication through the use of conventional welding methods. The chromium-nickel steel used has, by virtue of the particular combination of elements therein, both the remarkable ability to be worked during the product manufacturing operations and to withstand conditions surrounding the use of the resulting finished products.

Thus it will be seen that there is provided in this invention austenitic chromium-nickel alloy gas turbine parts or articles in which the various objects noted, together with many thoroughly practical advantages are successfully achieved. It will be seen that the turbine parts are tough, strong, durable, corrosion-resistant, heat-resistant and are especially adapted to withstand continuous high temperature duty over long periods of time and under the many conditions of actual practical use.

While the invention is particularly concerned with gas turbines and their associated rotors, buckets and the like, I find that high-temperature steam turbines satisfactorily are constructed in accordance with my invention. Satisfactory operation of such turbines is had at temperatures of 1000° F. to 1100° F., or higher.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiment hereinbefore set forth, it is to be understood that all matter described herein is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. Turbine parts of austenitic stainless steel, with any ferrite only in traces, comprising 12% to 22% chromium, 10% to 21% nickel, 0.10% to 2% manganese, 2% to 4% molybdenum, 2% to 4% copper, 0.15% to 0.75% titanium, 0.20% to 1.10% columbium, 0.01% to 0.15% carbon, and remainder iron, characterized by resistance to fatigue and creep and by resistance to attack by corrosive gases under conditions of high temperatures.

2. Wrought turbine parts comprising 17% chromium, 13% nickel, 1% to 1.5% manganese, 3% molybdenum, 3% copper, 0.25% titanium and 0.40% columbium, 0.10% maximum carbon, and remainder iron, said parts being fully austenitic and characterized by resistance to fatigue and creep and by resistance to attack by corrosive gases under conditions of high temperatures.

3. A turbine bucket comprising 12% to 22% chromium, 10% to 21% nickel, 0.10% to 2% manganese, 2% to 4% molybdenum, 2% to 4% copper, 0.15% to 0.75% titanium, 0.20% to 1.10% columbium, 0.01% to 0.15% carbon, and remainder principally iron, characterized by a fully austenitic structure and by resistance to fatigue

and creep and by resistance to attack by corrosive gases under conditions of high temperatures.

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