Dec. 22, 1931. H. HOLZWARTH 1,837,439

TURBINE BLADE FOR GAS AND STEAM TURBINES

Filed March 19, 1929

Fig. 1.

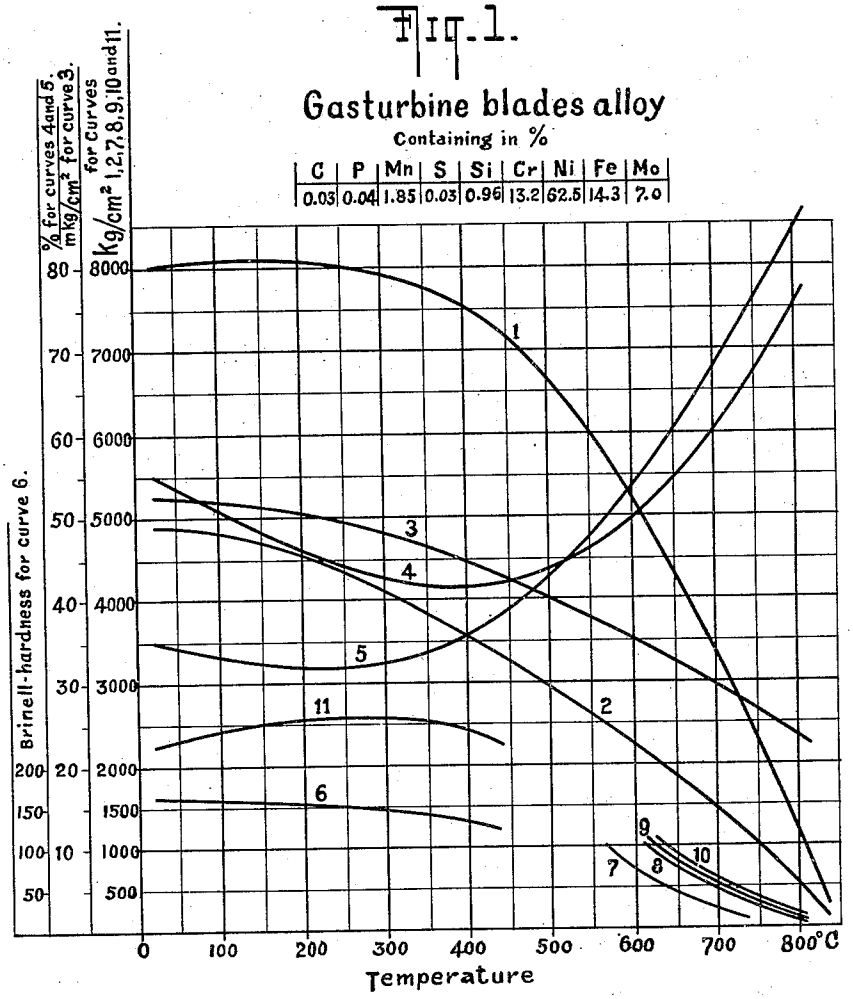
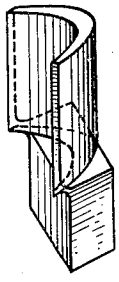


Fig. 2.



WITNESS

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UNITED STATES PATENT OFFICE

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TURBINE BLADE FOR GAS AND STEAM TURBINES

Application filed March 19, 1929, Serial No. 348,316, and in Great Britain April 23, 1928.

The present invention relates to turbine blades for gas and steam turbines disclosed in my copending application for patent Serial No. 186,093, filed April 23rd, 1927, wherein a turbine blade is described which is composed of an alloy containing from 60 to 65% of nickel, 12 to 15% of chromium, 10 to 12% of iron, and about 7% of molybdenum; the present application is a continuation in part of the application referred to.

The rotor and stator blades of gas turbines must be capable of resisting oxidation and erosion if they are to remain in continuous operation at practically constant efficiency, must have sufficient strength to resist fatigue and the strains tending to stretch and deform them, and should be able to maintain their strength and elasticity at the high temperatures to which they are subjected, which may reach 750° C. They should, furthermore, be made of a material which allows them to be forged and machined readily. Above all, however, the material should be capable of a high resistance to creeping (Kriechfestigkeit), that is, it should have the quality of maintaining its original dimensions while subjected to high temperature under load. The free edges of these blades must of necessity be arranged very close to other parts of the apparatus, for instance, other blades, the turbine housing, or the charging nozzles, and the more closely they can be so arranged and maintained the better, other things being equal, is the performance of the apparatus. If the material has a tendency to creep, one or more edges of the blades will eventually come into contact with adjacent material, or the blades have to be spaced from such material at a distance greater than is desirable for most efficient operation.

I have found that an alloy of the following formula meets all the conditions hereinabove specified, and above all the condition that turbine blades made of such material will not creep to such an extent as to interfere with efficient construction and operation of an explosion gas turbine: 62.5% of nickel, 13.2% of chromium, 14.3% of iron, and 7.0% of molybdenum. The remaining portion (about 3%) consists of traces of phosphorus, manganese, sulfur and silicon.

In the annexed drawings Fig. 1 represents a compilation of the physical and chemical properties of an alloy, whose composition is given above; while Fig. 2 shows a turbine blade embodying the present invention.

The particular material just described has a tensile strength under continuous run conditions as follows (curve 1—ultimate tensile stress)

	Kg. per square centimeter
at 300° C.	7,900
400° C.	7,550
500° C.	6,700
600° C.	5,200
700° C.	3,300
800° C.	1,200

Its elongation (curve 5—of the drawings) under similar conditions, was found in test bars with lengths equal to ten times their diameters to be as follows

	Per cent
at 300° C.	32
400° C.	36
500° C.	43
600° C.	53.5
700° C.	68
800° C.	85

Its elastic tensile limit, i. e. the limit of proportionality between stress and strain (curve 2) was found under similar conditions, to be as follows:

	Kg. per square centimeter
at 300° C.	4,100
400° C.	3,600
500° C.	2,950
600° C.	2,200
700° C.	1,400
800° C.	500

Its resistance to denting (curve 3—energy to fracture in notched bar impact test) was

found, under similar conditions, to be as follows:

	Mkg. per square centimeter
at 300° C.	48
400° C.	44.5
500° C.	40.0
600° C.	35
700° C.	29.5
800° C.	23

Curve 4 indicates the % reduction in area with increase of temperature, while curve 6 shows the change in the hardness of the alloy, such hardness determined by the Brinell method.

Its creeping limit (curve 7—limiting creep stress), under similar conditions, was found to be as follows:

	Kg. per square centimeter
at 560° C.	1,000
600° C.	700
650° C.	400
700° C.	230

Finally, the stress under which the test bar (blade) creeps 1% of its length after 10 000 hours of operation under similar conditions, was found to be as follows (curve 9 of the drawings):

	Kg. per square centimeter
at 620° C.	1,000
650° C.	770
700° C.	500
750° C.	265

Curves 8 and 10 indicate the stresses required to produce 1% creeping after 20,000 and 5,000 hours of operation, respectively. At 1,000° C. the power of this alloy to resist oxidation is four hundred times as great as the power of iron to resist oxidation at 800° C.

In the preferred form of my invention the ingredients constituting the alloy are mixed in a molten condition while the mixture is subjected to a vacuum sufficient to remove any gases or substantially all of the gases which may be present, so that there will be substantially no gases occluded in the cooled material. The tests of which the results are hereinabove given were made with material so treated during manufacture.

Slight changes in the percentage of the ingredients constituting the alloy will of course change somewhat the physical properties of this alloy, but such changes will not be material if the proportions of the several ingredients are kept substantially within the following limits: 60% to 65% of nickel, 12% to 15% of chromium, 10% to 16% of iron.

I have found that the property of resistance to creeping is not a function of either tensile strength, elastic tensile limit, resistance to denting or, so far as is known to me, of any other property of an alloy, and therefore, other things being equal, appears to be quite independent of any other property of an alloy. For instance, I found that an alloy with 58% of nickel, 15% of chromium, 12% of iron, 3% of molybdenum, 3% of cobalt and 5% of tungsten shows under similar conditions a tensile strength at 600° C. of 5,900 kg. per square centimeter, 700° C. of 4,450 kg. per square centimeter, 800° C. of 2,000 kg. per square centimeter, and a resistance to denting at 600° C. of 42.5 mkg. per square centimeter, 700° C. of 41,0 mkg. per square centimeter, 800° C. of 32.0 mkg. per square centimeter, while the stress under which the test bar (blade) creeps 1% of its length after 10,000 hours of operation, under similar conditions was found to be as follows:

	Kg. per square centimeter
at 700° C.	370
750° C.	175

Although the general physical properties of this chromium—nickel—molybdenum alloy with additional content of tungsten and cobalt are superior to the gas turbine blade alloy as claimed by me, nevertheless the resistance to creeping is reduced by such variation in composition to about ⅔ of the corresponding values of the alloy according to my invention. This loss of creeping strength is of great significance, as the resistance to creeping is decisive for the design of the blade, the admissible maximum length of the same and the maximum power obtainable from such a gas turbine.

I claim:

1. A turbine blade for gas and steam turbines capable of resisting high temperatures and having a high resistance to creeping, composed of an alloy containing 60% to 65% of nickel, 12% to 15% of chromium, 10% to 16% of iron, and about 7% of molybdenum.

2. A turbine blade for gas and steam turbines capable of resisting high temperatures and having a high resistance to creeping, composed of an alloy containing 60% to 65% of nickel, 12% to 15% of chromium, 10% to 16% of iron, and about 7% of molybdenum, and substantially free from occluded gases.

3. A turbine blade for gas and steam turbines capable of resisting high temperatures and having a high resistance to creeping, composed of an alloy containing 62.5% of nickel, 13.2% of chromium, 14.3% of iron, and 7.0% of molybdenum.

HANS HOLZWARTH.