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NICKEL CHROMIUM BASE ALLOY AND A STATIONARY TURBINE BLADE MADE THEREFROM

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Fig. 1.

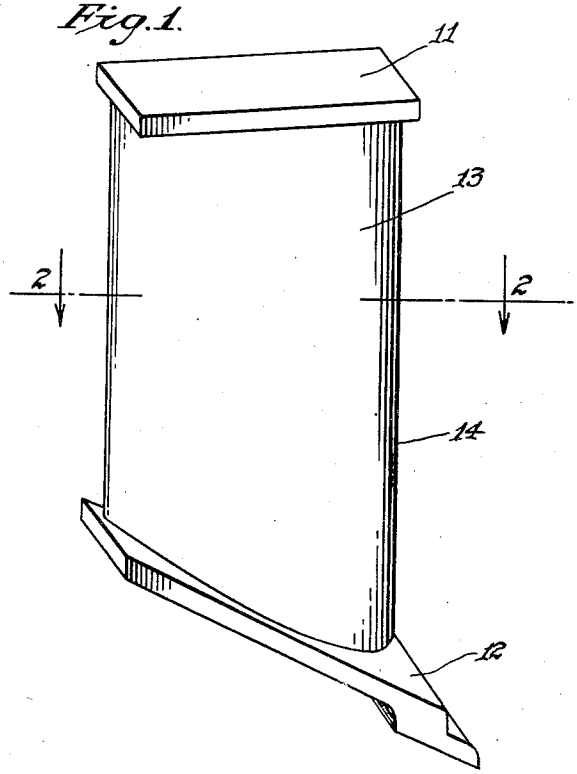


Fig. 2.

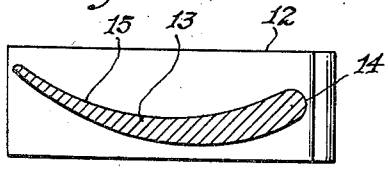


Fig. 3.

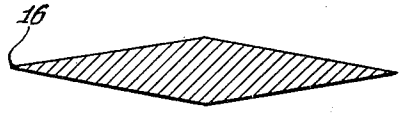
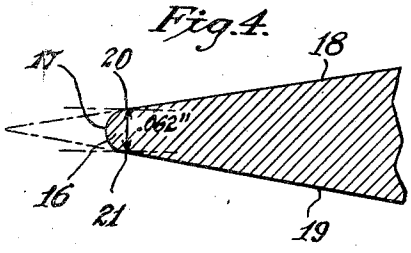


Fig. 4.



HAROLD E. GRESHAM
MARCUS A. WHEELER
INVENTORS.

BY

Kenyon & Kenyon
ATTORNEYS

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NICKEL CHROMIUM BASE ALLOY AND A STATIONARY TURBINE BLADE MADE THEREFROM

Harold Ernest Gresham, Little Eaton, and Marcus Alan Wheeler, Darley Abbey, England, assignors to Rolls-Royce Limited, Derby, England, a corporation of Great Britain

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Claims priority, application Great Britain October 25, 1952

10 Claims. (Cl. 75—171)

This invention relates to a nickel-chromium base alloy and to a stationary turbine blade for internal combustion turbine engines made therefrom.

Among the objects of the invention are to provide an alloy having the herein-named special properties at high temperature, and to provide a stationary turbine blade, for example, a nozzle guide vane, made from such alloy, having high resistance to thermal shock, low elongation under stress at high temperature, and high ultimate tensile strength at operating temperatures, these qualities serving to reduce the frequency of leading-edge cracks and of bending under gas load with resulting change in the throat area which are among the principal reasons for the present high rate of blade renewal required for the maintenance of internal combustion turbine engines used for aircraft propulsion. Blades made of our alloy according to this invention have a thermal shock index of at least 45, an elongation under load of 2 long tons per square inch in 100 hours at 950° C. of 1% or less, and an ultimate tensile strength at 950° C. of about 20 long tons per square inch.

Referring to the drawings attached hereto and forming part hereof—

Fig. 1 is a perspective view of one type of a stationary turbine blade according to this invention;

Fig. 2 is a horizontal cross-section in the plane 2—2 of Fig. 1;

Fig. 3 is a diagrammatic representation of a rhombic section of a solid; and

Fig. 4 is an enlargement of one end of the rhombic section of Fig. 3, including an acute angle edge thereof.

Referring to the drawings:

A stationary turbine blade made of our alloy according to this invention comprises outer and inner flange members 11 and 12 formed integral with the blade member 13 which joins them together. Blade 13 is suitably shaped in cross-section (see Fig. 2) to divert gaseous combustion products received on either side of its leading edge 14 towards the moving blades of the turbine wheel (not shown). The general engine structure is well known, being shown in Lombard Patent No. 2,494,821, granted January 17, 1950, to which reference is made. In such structure, when the engine is running at full power, blade 13 is subject to the impact of a gas stream whose temperature is about 950° C., and to heavy gas bending loads applied to the concave surface 15 of the blade. When such an engine, for example in aircraft use, is shut down, the high temperature gas stream is almost instantly replaced by a stream of cold air whose temperature may in some cases be very low. In consequence,

the blade is exposed in use to extreme and rapid changes of temperature, and the resulting thermal shock manifests itself in the formation of cracks along the leading edge 14. Furthermore, the heavy bending stress applied to concave surface 15 while the blade is hot tends to cause permanent deformation, sometimes requiring replacement of the blade after as little as 60 hours flying time with the blades now in use. Either or both of these effects severely limits the life of blades now in use, particularly as operating temperatures become higher with increased engine output.

Two well-known alloys are now currently used for stationary turbine blades. One of these which is herein called "alloy X" has the approximate composition by weight of 13.88% chromium, 17.82% molybdenum, 4.07% tungsten, 0.17% carbon, 4.72% iron and the balance (a little less than 60%) nickel plus usual cleansers, deoxidizers and impurities. The other which is herein called "alloy Y" has the approximate composition by weight of 23.22% chromium, 11.75% nickel, 2.52% tungsten, 0.24% carbon and the balance (about 52%) iron plus usual cleansers, deoxidizers and impurities.

According to the present invention a stationary turbine blade 13 is made of an alloy having by weight approximately the following composition:

	Percent
Chromium	18–22
Molybdenum	8–10
Titanium	2–3
Aluminium	0.5–2

and the balance nickel plus usual cleansers, deoxidizers and impurities but the impurities cobalt, carbon and iron respectively should not exceed about 1% cobalt, 0.15% carbon and 1% iron. The cleansers manganese and silicon may each be used up to a maximum of about 1% each. While about 0.15% is the maximum for carbon, it is preferred that carbon be kept below 0.10%.

One of the objects of our invention being to produce a turbine blade, and an alloy suitable for use therein, having the specified high temperature properties and to do this without resort to the use of cobalt, we specify above that cobalt is to be treated as an impurity and kept below about 1%. Investigation indicates that the addition of cobalt up to as much as 10% will bring about no appreciable improvement in the alloy. According to the invention, therefore, cobalt which is a costly and strategic material, may be omitted altogether if desired.

The amount of chromium which may be used is governed largely by the need for oxidation resistance at high temperature. This quality is at its best when the chromium is approximately within the range 18 to 22%.

When molybdenum is less than about 8% the high thermal shock properties of the blade and alloy of the present invention fall off and bending of the blade occurs under gas load, while if the molybdenum is more than about 10% no appreciable or further improvement in these properties is obtained.

If the aluminium is below about 0.5%, the strength of the alloy, and consequently of a blade made of it, is insufficient to meet operational requirements. If the aluminium is much above about 1.2%, the otherwise excellent properties of the alloy begin to be offset by a tendency of the blade to be too strong to be straightened when cold. In the production of stationary turbine blades by casting it is sometimes necessary that the blade have

sufficient cold ductility to permit its being straightened after casting in order to counteract warpage. As the aluminium is increased above about 1.2% the degree of cold ductility required for this straightening falls off rapidly. However, where casting techniques are such that subsequent cold-straightening is not required, the aluminium content may be up to 2% with advantage to creep strength whilst maintaining good thermal shock properties. An aluminium content in excess of about 2% gives rise to excessive hardness which renders machining operations difficult.

Similar considerations apply with respect to the inclusion of titanium. That is, below about 2% the blade has insufficient strength, and above about 3% its cold ductility falls off. Also, when titanium is above about 3% the thermal shock properties of the alloy deteriorate.

Manganese and silicon are added mainly as cleansing elements. If the alloy is to be used in the wrought condition, manganese and silicon should be kept as low as possible, with the content of these elements together not in excess of 1%.

Iron and carbon, which occur as impurities, should be kept as low as possible, and preferably within the ranges stated for them respectively.

Other known cleansing and deoxidizing elements may be present.

In order to test the thermal shock properties of turbine blades, a rhombic section test-piece of the alloy precisely cast to size is heated rapidly from room temperature (15° C.) to a controlled maximum temperature of 930° C. in approximately 55 seconds, this temperature being maintained for 5 seconds. The test specimen is then cooled from 930° C. to 50° C. in approximately 20 seconds by a spray of water or compressed air or both. Thereafter the spray is maintained for a further 40 seconds to bring the metal back to room temperature, whereupon the test is repeated. The rhombic section is cast in such manner (see Figs. 3 and 4) as to have an acute angle edge 16 which, in section, consists of the arc of a circle 17 tangent to the sides 18 and 19 of the rhombic section at points 20 and 21 respectively. In the tests hereinafter mentioned the distance between points of tangency 20 and 21 is approximately .062 inch. In these tests the "thermal shock index" is the number of cycles of temperature variation from 15° C. to 930° C. to 50° C. to 15° C. which produces a crack completely across the acute angle edge from 20 to 21.

Example 1

An example of an alloy according to this invention has the specific composition of

	Percent
Chromium	20
Molybdenum	9.24
Titanium	2.99
Aluminium	0.75
Carbon	.04

and the balance nickel plus the usual cleansers, deoxidizers and impurities, with iron, manganese, cobalt and silicon each less than 1% (total of the balance being about 67%).

The above alloy was found to have a thermal shock index of 52. This may be compared with alloy X which was found to have a thermal shock index of 30, and with alloy Y which was found to have a thermal shock index of 28.

When the above alloy according to this invention was subjected to a load of two long tons (4480 lbs.) per square inch for 100 hours at 950° C., it was found to have an elongation of 1%. Under like conditions alloy X had an elongation of 1.1% and alloy Y an elongation of 5.5%.

The above alloy according to this invention was tested for ultimate tensile strength at 950° C. Fracture occurred under load of approximately 20 tons (44,800 lbs.) per square inch. Under like test alloy X fractured under load of 15 tons, and alloy Y under load of 10 tons. The above alloy possessed sufficient ductility to permit cold straightening of cast blades where required.

Example 2

Another example of an alloy according to this invention has the specific composition of:

	Percent
Chromium	20
Molybdenum	8.44
Titanium	2.10
Aluminium	1.83
Carbon	0.06

and the balance nickel plus the usual cleansers, deoxidizers and impurities, with iron, manganese, cobalt and silicon each less than 1% (total of the balance being about 67%).

The above alloy was found to have a thermal shock index of 50. Subjected to a load of two long tons (4480 lbs.) per square inch for 100 hours at 950° C. it was found to have an elongation of 0.31%. The ultimate tensile strength at 950° C. is approximately 20 tons per square inch.

The above alloy has good creep and thermal shock properties, but the relatively high aluminium content (1.83%) reduces cold ductility to such an extent that a blade cast in this alloy cannot be readily straightened when cold. However, this alloy is useful where the casting is true to shape.

Example 3

Another example of an alloy according to this invention has a specific composition of

	Percent
Chromium	20.8
Molybdenum	9.82
Titanium	2.64
Aluminium	0.95

The balance was as in the examples given above.

The thermal shock index of this alloy is approximately 50, while the elongation under a load of two long tons (4480 lbs.) per square inch for 100 hours at 950° C. has been found to be 0.2%. Again the ultimate tensile strength at 950° C. is approximately 20 tons (44,800 lbs.) per square inch. This alloy has sufficient ductility to permit cold straightening if necessary.

Example 4

A suitable material specification for use in the production of turbine blades is as follows:

	Percent
Chromium	20–22
Molybdenum	8.5–10
Titanium	2.2–2.8
Aluminium	0.5–0.9
Carbon	0.10 maximum
Iron	1 maximum
Silicon	1 maximum
Manganese	1 maximum
Cobalt	1 maximum

Blades made of this material have a thermal shock index of approximately 45 or better, an elongation under load of 2 long tons per square inch for 100 hours at 950° C. of not substantially more than 1%, and an ultimate tensile strength at 950° C. of about 20 long tons per square inch.

The blades according to this invention may be made either by casting or by forging. While the alloy is primarily intended for use in the as cast condition, it may be used as a wrought alloy in the fully heat treated condition. A suitable heat treatment is solution heat treatment at 1200° C. for 1½ hours, followed by 4 hours at 1080° C. followed by aging treatment at 750° C. for 16 hours.

What is claimed is:

1. An alloy having a thermal shock index at 930° C. of at least about 45, an elongation not substantially more than 1% under load of 2 long tons per square inch in 100 hours at 950° C., and an ultimate tensile strength at 950° C. of about 20 long tons per square inch, said alloy consisting by weight approximately of 18% to 22% chromium, 8% to 10% molybdenum, 2% to 3% titanium, 0.5% to 2% aluminium, the impurities carbon and iron not exceeding respectively about 0.15% carbon and 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

2. An alloy having a thermal shock index at 930° C. of at least about 45, an elongation not substantially more than 1% under load of 2 long tons per square inch in 100 hours at 950° C., and an ultimate tensile strength at 950° C. of about 20 long tons per square inch, said alloy consisting by weight approximately of 20% to 22% chromium, 8.5% to 10% molybdenum, 2.2% to 2.8% titanium, 0.5% to 0.9% aluminium, the impurities carbon and iron not exceeding respectively about 0.10% carbon and 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

3. An alloy having a thermal shock index at 930° C. of about 52, an elongation of about 1% under load of 2 long tons per square inch in 100 hours at 950° C., and an ultimate tensile strength at 950° C. of about 20 long tons per square inch, said alloy consisting by weight approximately of 20% chromium, 9.24% molybdenum, 2.99% titanium, 0.75% aluminium, 0.04% carbon, not more than about 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

4. An alloy having a thermal shock index at 930° C. of about 50, an elongation of about 0.31% under load of 2 long tons per square inch in 100 hours at 950° C., and an ultimate tensile strength at 950° C. of approximately 20 long tons per square inch, said alloy consisting by weight approximately of 20% chromium, 8.44% molybdenum, 2.10% titanium, 1.83% aluminium, 0.04% carbon, not more than about 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers, and impurities.

5. An alloy having a thermal shock index at 930° C. of about 50, an elongation of about 0.2% under load of 2 long tons per square inch in 100 hours at 950° C., and an ultimate tensile strength at 950° C. of about 20 long tons per square inch, said alloy consisting by weight approximately of 20.8% chromium, 9.82% molybdenum, 2.64% titanium, 0.95% aluminium, the impurities carbon and iron not exceeding respectively about 0.15% carbon and 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

6. A stationary turbine blade for an internal combustion turbine engine which comprises an alloy consisting by weight approximately of 18% to 22% chromium, 8% to 10% molybdenum, 2% to 3% titanium, 0.5% to 2% aluminium, the impurities carbon and iron not exceeding respectively about 0.15% carbon and 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

7. A stationary turbine blade for an internal combustion turbine engine which comprises an alloy consisting by weight approximately of 20% to 22% chromium, 8.5% to 10% molybdenum, 2.2% to 2.8% titanium, 0.5% to 0.9% aluminium, the impurities carbon and iron not exceeding respectively about 0.10% carbon and 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

8. A stationary turbine blade for an internal combustion turbine engine which comprises an alloy consisting by weight approximately of 20% chromium, 9.24% molybdenum, 2.99 titanium, 0.75% aluminium, 0.04% carbon, not more than about 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

9. A stationary turbine blade for an internal combustion turbine engine which comprises an alloy consisting by weight approximately of 20% chromium, 8.44% molybdenum, 2.10% titanium, 1.83% aluminium, 0.04% carbon, not more than about 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers, and impurities.

10. A stationary turbine blade for an internal combustion turbine engine which comprises an alloy consisting by weight approximately of 20.8% chromium, 9.82% molybdenum, 2.64% titanium, 0.95% aluminium, the impurities carbon and iron not exceeding respectively about 0.15% carbon and 1% iron, and the balance essentially nickel and the usual deoxidizers, cleansers and impurities.

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