Dec. 26, 1961 P. G. TURNER 3,014,692

GAS TURBINE BLADES

Filed Dec. 4, 1957

FIG. 1.

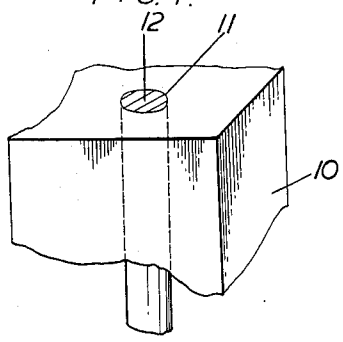


FIG. 2.

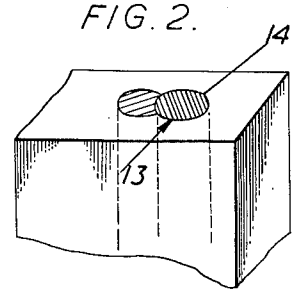


FIG. 3.

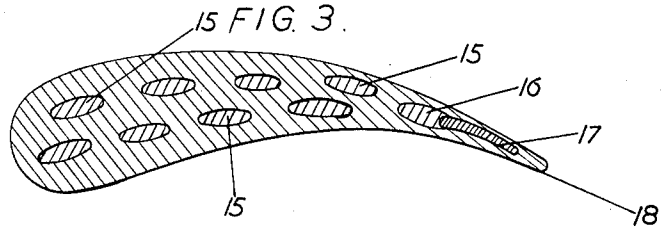
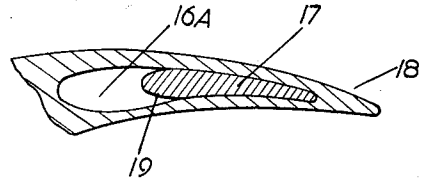


FIG. 3A.



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GAS TURBINE BLADES

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2 Claims. (Cl. 253—39.1)

The present invention relates to turbine blades and, more particularly, to the manufacture of gas turbine blades having longitudinal fluid cooling passages therein.

It is well known that because of the very high temperatures to which gas turbine blades are subjected in use, passages for the flow of cooling air are sometimes made in them. It is particularly important to cool the trailing edge of the blade and to use a plurality of small holes of lenticular shape when viewed in section—see D.G. Ainley's paper: The High-Temperature Turbo-jet Engine Journal of the Royal Aeronautical Society, September 1956, p. 571, paragraph 8.2 in which a parameter equal to $(S/c)^{1.2}/(A/c^2)$ and called the Z factor is used to compare the relative efficiency of various cooling methods. S is the internal surface area of cooling passages per unit blade height. A the cross-sectional flow area of cooling passages and c the blade chord. The blades of the invention have cooling passages giving a high Z factor but the practicability of the necessarily small holes in the trailing edge is adversely affected by its liability to blockage or choking from foreign matter entrained in the coolant stream. If the passage in the trailing edge is choked, the trailing edge will rapidly become so hot that the metal at the edge melts or burns away.

Although many attempts were made to overcome the foregoing difficulty and other disadvantages, none, as far as I am aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that by means of a special configuration of co-operating structural components a novel internally cooled turbine blade may be provided.

It is an object of the present invention to provide a novel fluid cooled turbine blade having improved heat transmission characteristics.

Another object of the invention is to provide a method for producing said novel fluid cooled turbine blade having improved heat transmission characteristics.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a cross-sectional view of a turbine blade embodying the novel concepts of the present invention.

According to this invention, the part of the fluid cooled turbine blade close to the leading and/or trailing edge thereof is made of molybdenum or a molybdenum-base alloy in a skin of the metal of the blade which may be a creep-resisting nickel-chromium alloy, including nickel-chromium-iron and nickel-chromium-cobalt base alloys. These nickel-chromium alloys may contain small amounts of aluminum and titanium. By a molybdenum-base alloy is meant an alloy containing at least 80% molybdenum; such alloys normally contain 99% molybdenum or more, an example being the alloy composed of 99.5% molybdenum and 0.5% titanium. Other such alloys may contain a small amount of zirconium, vanadium or niobium, the remainder being molybdenum. All these alloys will be referred to hereinafter as "molybdenum" for the sake of convenience.

The molybdenum in the trailing edge of the blade has much higher thermal conductivity than the creep-resisting alloys used for turbine blades and so conducts heat away

from the trailing edge. Most advantageously, a passage for the flow of air is made along the side of the molybdenum remote from the trailing edge, i.e., this passage is at least partly bounded by the molybdenum.

In effect the usual cooling passage closest to the trailing edge is eliminated and in its place there is a length of molybdenum, preferably (as seen in cross section) extending up to the end forming part of the wall of the next of the usual cooling passages.

Molybdenum oxidizes extremely readily in the presence of oxygen at high temperatures such as encountered in modern gas turbines and it is necessary to provide an oxidation-resistant coating on the surface of the molybdenum exposed to cooling air. This coating advantageously consists of a nickel-chromium-iron alloy, e.g., an alloy containing about 78% nickel, 14% chromium and 6% iron, or alternatively, a coating of palladium. This coating may be present as a thin sheath bonded to the molybdenum by nickel electrodeposited on the molybdenum.

In carrying the invention into practice with regard to the manufacture of the novel turbine blade of the present invention, the molybdenum is introduced into the blade as a sheathed rod inserted into a hole drilled in a billet from which the blade is made, other holes in this billet being filled with a material such as an iron-manganese-titanium alloy, which flows with the metal of the billet during extrusion or other hot working operations and which is subsequently removed to leave the required cooling passages. The molybdenum will flow with the metal of the billet in the same way as the filler alloy. The removal of the filler alloy is usually effected by acid-leaching and during this process the molybdenum is protected from the leaching acid by its protective sheath.

If the molybdenum is to form part of the wall of a cooling passage, the hole made in the billet to receive the sheathed molybdenum must be large enough also to receive a filler rod and the two rods must be in contact with or abutting one another before the billet is extruded or otherwise worked.

When employing the aforementioned sheathed molybdenum inserts the insert should be in contact with the side wall of the hole and substantially in contact with and co-extensive with any filler material also inserted therein. Suitable filler materials for use in the present process advantageously are ferritic iron alloys containing about 1% to about 10% titanium and about 5% to about 20% manganese. Other sheathing materials which may be used can be selected from the group consisting of nickel; nickel-chromium; nickel-chromium-iron; precious metals, platinum, palladium; titanium and zirconium. All these materials are metals having melting points greater than about 1250° C. The sheaths not only protect the molybdenum from destructive oxidation at elevated temperatures but also protect the molybdenum from the deleterious effect of acids used in removing the aforementioned fillers. It is to be noted that prior to or subsequent to the removal of the filler, the extruded turbine blade may be subjected to operations such as machining, polishing, twisting, etc.

Referring now to the drawing, it is to be observed that:

FIGURES 1 and 2 are sectional views of a portion of a parallelepiped billet before extrusion.

FIGURE 3 is a sectional view of a turbine blade extruded from the billet of FIGURES 1 and 2.

FIGURE 3A is an enlarged view of the trailing edge of the blade shown in FIGURE 3.

Referring now specifically to the figures. A billet **10** is drilled to provide inter alia a cylindrical hole **11** at such a position that in a subsequent extrusion operation

the hole will lie close to the trailing edge of the blade. The hole **11** is then filled with filler rod **12**. A second hole **13** (FIGURE 2) is then drilled to overlap the filled hole **11**. The hole **13** is then filled with a core **14** of molybdenum coated with an oxide resistant layer. The billet is then extruded to provide an aerofoil section (FIGURE 3) containing a plurality of filled cooling passages **15** as understood in the art; a filled passage **15** and a molybdenum heat sink **17** in the trailing edge **18**. From FIGURE 3A it will be seen that after acid leaching of the filler the passage **16A** contains as a portion of its side wall the heat sink **17** comprising a main mass of molybdenum sheathed in an oxide resistant layer **19**.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. A gas turbine blade adapted to be used at high temperatures which comprises a substantially elongated segment of heat-resistant metal having an airfoil configuration along at least part of its length, having a plurality of cooling passages extending substantially longitudinally therethrough and having a sheathed insert of molybdenum extending substantially longitudinally therethrough situated adjacent the trailing edge thereof and forming at least a part of a wall of one of said cooling passages.

2. A gas turbine blade adapted to be used at high temperatures which comprises a substantially elongated segment of heat-resistant metal having an airfoil configuration along at least part of its length, having a plurality of cooling passages extending substantially longitudinally therethrough and having a sheathed insert of molybdenum extending substantially longitudinally therethrough situated adjacent the trailing edge thereof.

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