Aug. 11, 1953

H. E. SCHMITT

2,648,520

AIR-COOLED TURBINE BLADE

Filed Aug. 2, 1949

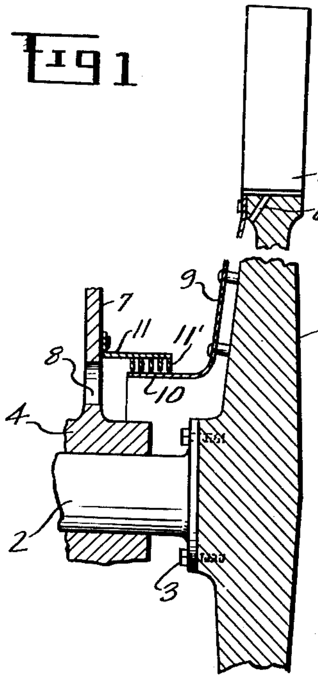
FIG 1

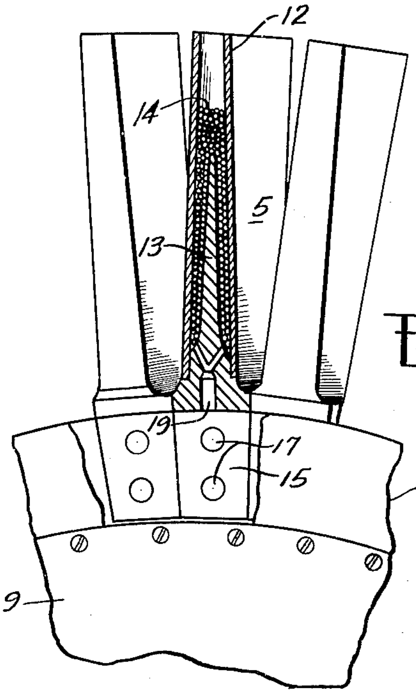
FIG 2

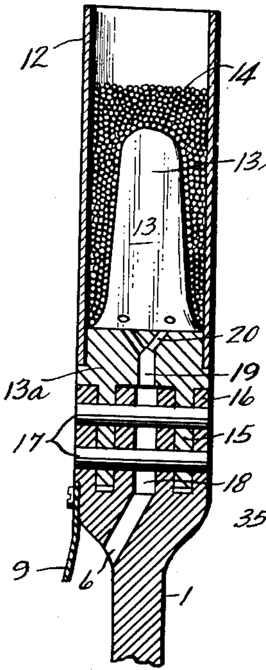
FIG 3

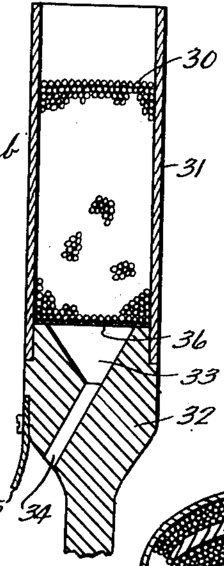
FIG 4

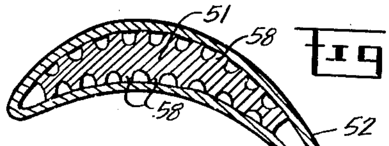
FIG 7

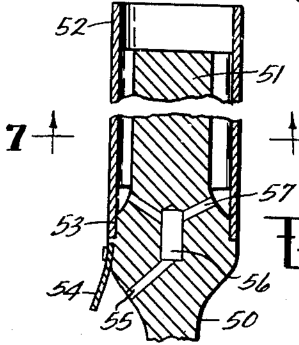
FIG 6

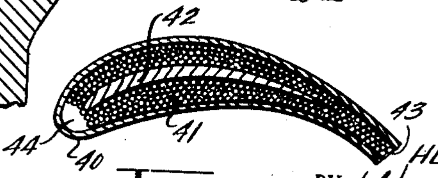
FIG 5

INVENTOR.
HEINZ E. SCHMITT
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne
AGENT

Patented Aug. 11, 1953

2,648,520

UNITED STATES PATENT OFFICE

2,648,520

AIR-COOLED TURBINE BLADE

Heinz E. Schmitt, Dayton, Ohio

Application August 2, 1949, Serial No. 108,175

3 Claims. (Cl. 253—39.15)

(Granted under Title 35, U. S. Code (1952), sec. 266)

1

The invention described herein may be manufactured by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

The present invention relates to air cooled turbine blade constructions, particularly for use in combustion turbines where the blades operate at very high temperatures.

The primary object of the invention is to provide an improved air cooled turbine blade including a hollow sheet metal blade enclosing a porous or channeled metallic core to afford a multiplicity of cooling air passages and a maximum of heated surface exposed to the cooling medium in heat exchange relation.

A further object of the invention is to provide an improved air cooled turbine blade including a hollow sheet metal blade exposed to the hot gases flowing from a combustion chamber and enclosing a central core member anchored to the turbine wheel and also secured to the sheet metal blade in such a way as to provide a multiplicity of channels for the passage cooling air between the sheet metal blade and the central core member, so that the core member being maintained at a lower temperature than the sheet metal blade is able to withstand higher unit stresses and strengthen the whole blade structure accordingly.

A further object of the invention is to provide an air cooled turbine blade having a longitudinally extending core member within a sheet metal outer blade member with securing means connecting the core member and sheet metal outer blade member together.

A further object of the invention is to generally improve the mechanical strength and cooling efficiency of air cooled turbine blades.

The above and other objects of the invention will become apparent upon reading the following detailed description in conjunction with the accompanying drawing, in which:

Fig. 1 is a cross sectional view of portions of a turbine wheel and an associated bearing.

Fig. 2 is a fragmentary view of a turbine wheel looking at the face of the wheel and showing three adjacent blades, one of which is in longitudinal cross section.

Fig. 3 is a longitudinal cross sectional view of a turbine blade like that shown in Fig. 2 but taken across the width of the blade.

Fig. 4 is a longitudinal cross sectional view of a turbine blade similar to that of Fig. 3 but omitting the solid central blade core.

Fig. 5 is a transverse cross sectional view taken through a modified turbine blade having an open trailing edge to permit cooling air flow across the width of the blade.

Fig. 6 is a longitudinal cross sectional view taken through a turbine blade having a finned core member therein.

2

Fig. 7 is a cross sectional view taken on line 7—7 of Fig. 6.

In gas turbines it is imperative that the turbine blades be capable of withstanding very high temperatures for long periods of time. While it is common practice to use solid blades made of heat resisting alloy steels, it is also possible to use hollow blades having a cooling medium circulating therethrough. Such hollow blades may be constructed of steels containing smaller quantities of scarce alloying elements. Being held at lower and more uniform temperatures, these hollow blades have less tendency to warp and twist. Also there is less danger of the blades failing under stress because the temperature of the metal is held down by the circulating cooling medium.

In Fig. 1 there is shown a portion of a turbine wheel as found in a gas turbine, such as that shown in complete cross sectional form on page 393 of "Gas Turbine Construction" (1947) by R. Tom Sawyer. The wheel **1** is secured to a flanged main shaft **2** by bolts **3** and one bearing **4** is shown to rotatably journal the shaft **2**. The wheel **1** carries on its periphery a continuous series of blades, as at **5**, which are made hollow to receive cooling air entering at **6** and leaving the open ends of the blades for passage rearwardly with the turbine exhaust gases. Cooling air may be diverted from the engine compressor and passed through an annular conduit coaxial with respect to the shaft **2**. The bearing supporting flange **7** is apertured at a number of points to provide air flow ports **8** for passing the cooling air to the space around the forward side of the wheel **1**. The wheel carries a thin manifold plate **9** to confine the cooling air and channel it to the passages **6** extending into each blade **5**. The plate is formed outwardly into a cylindrical flange **10** having adjacent thereto another cylindrical flange **11** carried on the bearing flange **7**. The flange **11** also carries a series of ring-like flanges **11'** in spaced relation to form a labyrinth seal for preventing loss of cooling air. Thus it is seen that high pressure air is free to flow into the space between the wheel **1** and the manifold plate or disk **9** to feed air through the passages **6** and thence into each turbine blade.

Considering a preferred form of turbine blade construction as shown in Figs. 2 and 3, it will be seen that the wheel **1** carries a series of radially extending blades **5**. Each blade includes a shell **12**, a combined core and root member **13** and a porous filler **14**. The member **13** has a thick block-like root portion **13***a* having tongues **15** interfitting with respect to annular flanges **16** on the wheel **1**, and secured by means of transverse pins **17** driven into place or otherwise fastened securely. Along the central plane of the wheel **1** there is provided an annular groove **18** to receive cooling air by way of the passages **6**. Communicating with the groove **18** is an air passage **19** in each blade opening into a plurality of narrower passages **20** which extend to the outer surface of member **13** outwardly of the point where the core member begins tapering down. The tapered core portion **13***b* is spaced from the blade shell on all sides to provide cooling air spaces. These spaces are filled with metallic spheres or particles bonded to each other and to the blade shell and blade core. Such bonding may be accomplished by brazing and by using just the right amount of brazing material the bond is such as to provide an almost infinite member of passages or channels for the flow of cooling air toward the outer end of the blade. When the bonded particles are of spherical type the bonding is accomplished in such a way as to bond the balls or beads only at their points of tangency or over small areas adjacent to their points of tangency. The one piece tubular blade is welded or otherwise secured at its root end to the core member **13** adjacent to the inner end of the tapered core portion **13***b*. Furthermore the bonded filling material **14** is bonded both to the core portion **13***b* and to the sheet metal blade and thus provides further rigid connecting means between the well anchored member **13** and the shell **12**. The bonding or brazing material may be a copper base material but for heat resisting steel it is much preferred to use a silver-manganese material proportioned about 80 per cent silver and 20 per cent manganese. This alloy has a higher melting point than common copper brazing material and has the further advantage of reduced capillary action in the liquid state. Thus it will not penetrate the grain boundaries of the coarse structure usually found in heat resisting steel alloys. Such penetration by copper base brazes has been found to cause ultimate fatigue failure of metals under alternating stress or vibration. However for steels having fine grain structure, the copper brazes commonly used will be very satisfactory.

The outer blade shell **12** is exposed to very hot gases which flow to the turbine from the adjacent combustion chambers of the engine. Thus the shell soon reaches a high temperature and some of the heat is conducted through the shell material, thence into the filler material of foraminous or porous structure and also into the metallic core member **13**. Of the heat reaching the filler material, a major portion is picked up by the cooling air flowing through the interstices of the metallic filler. Thus only a minor portion of the heat conducted into the filler material from the blade shell ever reaches the core member **13**. Therefore the core will be maintained at a much lower temperature than the blade shell and can thus withstand a much higher unit stress than the material of the blade shell. The cooler core will function as an effective blade anchor for this reason and the filler material being bonded both to the core and to the blade shell will form a stress transferring means to hold the hot blade shell securely onto the cooler core or buttress **13**. Even though the blade shell is at very high temperature and can withstand comparatively low unit stress, it will be effectively held in place by the cooler core and the bonded filler material. The latter will chiefly resist sheer stress and will always be maintained at a low enough temperature to successfully resist such stress. The stresses which develop in the blades are of course due to the high centrifugal forces encountered at shaft speeds in the vicinity of 10,000 R. P. M. or higher. This centrifugal action which places the blade shell and the core member in tension also assists in promoting flow of cooling air outwardly through the foraminous blade filler to the open end of the blade. Insofar as possible the filler material is selected to have good heat conductivity, in order to permit heat to flow freely through the filler where the cooling air can have its effect in extracting heat from the blade interior. The filler particles or elements may take many geometrical shapes as tests prove most effective, but perfect cubes would probably be the least desirable shape. Various polygonal or spherical solid shapes may be employed or even crumpled and compacted sheet metal strips may be used in some cases. As explained above the tapered core portion **13***b* functions to rigidify the turbine blade, and to retain the filler particles by providing a central anchor therethrough and to transfer stress from the hot blade shell to the core and root member **13**.

In Fig. 4 there is illustrated a slightly different and less complicated blade structure. In this form of the blade the porous core or filler **30** entirely fills the shell **31** except for a small empty space at the outer end of the blade. The shell **31** may be brazed or welded at its inner end to the turbine wheel **32**. The wheel is annularly grooved as at **33** to provide a cooling air channel around the wheel, which channel is supplied with flowing air under pressure by a multiplicity of passages **34** extending to the forward side of the wheel. Cooling air is confined by means of a circular metal plate **35** arranged in a manner similar to the plate **9** of Fig. 1. The metallic particles bonded to each other and to the shell **31** to form the filler **30** are confined to a space outwardly of the channel or groove **33** by means of a screen **36** welded or brazed inside the shell. As in the first described form of the invention the filler material of bonded balls or beads is porous enough to permit the free flow of cooling air outwardly for ultimate discharge from the open end of the shell **31**. The filler material is not necessarily extended all the way to the open end of the shell, since the unit stress in the shell material decreases toward the tip end of the blade thus permitting higher shell temperatures. Sufficient heat transfer may be obtained by filling the shell only two-thirds to three-fourths full of bonded metal particles. Since the blade of Fig. 4 does not include the core member as in the first described form, it will not stand as high stresses but it will be very satisfactory for stationary blades or blades which rotate at moderate speeds.

In a third form of the turbine blade as shown in Fig. 5 the blade includes a shell **40**, a quantity of bonded filler particles **41** and a solid metallic core or anchor member **42**, as in the first described form of the invention. However in this modification the shell **40** of sheet metal is left open at the trailing edge **43**, so that cooling air can flow across the width of the blade from an air supply channel **44** in the leading edge of the blade. In this blade it is also noted that the tip end of the blade is completely closed off so that cooling air can only flow across the blade interior, not lengthwise thereof except in the air supply channel **44**. Other than these differences, the construction of the blade shown in Fig. 5 is quite similar to that of Figs. 2 and 3. The cooling air discharged from the trailing edge of the blade is heated and expanded considerably in passing through the filler material and will cause a force reaction on the blade to speed up its rotation. Thus the cooling air diverted from the engine compressor will not represent a direct power loss with this type of air cooled blade. Furthermore because of the rigidifying and strengthening effect of the core and filler, the use of a blade open along the trailing edge is more feasible and practical.

A fourth and final form of the present invention is illustrated in Figs. 6 and 7. As seen in Fig. 6 the turbine wheel **50** carries a series of ribbed extensions **51** extending radially outwardly with respect to the wheel. For each such extension there is a surrounding metal shell **52** slightly longer than the extension and secured as at **53** to the turbine wheel **50**. A manifold plate **54** secured to the wheel **50** provides a cooling air confining space opening into passage **55**, chamber **56** and transverse passages **57** extending to opposite sides of the core or extension **51**. The ribs **58** begin a short distance outwardly of the passages **57** to thus provide spaces extending across the blade to carry the cooling air to each of the channels or grooves between ribs **58**. The edge faces of the ribs **58** are bonded to the metal shell **52** as by brazing or welding, in order to conduct heat from the shell to the ribbed core member. The cooling air passing outwardly between the ribs **58** washes over the surfaces of the core member as well as over the inside surfaces of the shell **52**, thus carrying heat away from the inside of the blade at a steady rate. Here again the longitudinally extending core member will be cooler than the outer shell and better able to withstand tensile stresses than the shell. The brazed connections between the core ribs and the shell will be under shear stress but the total brazed area will be quite large and the unit shear stress will be small. By this arrangement the shell can successfully operate at higher temperatures than would be permissible without the stress carrying central core which is maintained at a lower temperature than the outer shell.

In describing the turbine blades it was assumed for purpose of illustration that they would be mounted on turbine wheels rotating at high speeds. However any or all of the described blades are adapted for use as stationary guides or vanes and will function in this application just as well on turbine wheels. The relative size of the metal filler particles may vary considerably. However if made too small there may be too high a resistance to flow of air and if made too large there may be too small a total cooling area for real results. If ball or spherical beads are used it is suggested that for average aircraft gas turbine blades the particles may range in diameter from one-sixteenth up to three-sixteenths of an inch.

The embodiments of the invention herein shown and described are to be regarded as illustrative only and it is to be understood that the invention is susceptible of variations, modifications and changes within the scope of the appended claims.

I claim:

1. In a gas turbine power plant including a source of high pressure air, a turbine blade construction comprising a metallic shell having a typical blade shape on its outer surface, means to retain said shell on a turbine wheel associated therewith including a longitudinally extending central metallic core member inside said shell and spaced from the inner surface of said shell, means on said core member to retain said member on the turbine wheel, means provided in said core member to conduct a minor portion of said high pressure air into one end of said metallic shell for passage between the shell wall and the core member, means providing at least one air escape opening from said metallic shell, and foraminous metallic means rigidly attached to the shell and the core member to support the shell on the core member at the same time providing an extensive heat transfer area exposed to said high pressure air circulating through said shell.

2. In a gas turbine power plant including a source of high pressure air, a turbine blade construction comprising a metallic shell having a typical blade shape on its outer surface, means to retain said shell on a turbine wheel including a longitudinally extending central metallic core member inside said shell and spaced from the inner surface of said shell, means connected to said core member to retain said member on the turbine wheel, means provided in said member to conduct a minor portion of said high pressure air into one end of said metallic shell for passage between the shell wall and the core member, means providing at least one air escape opening from said metallic shell, and metallic spheres inside said shell bonded to each other, to said shell and to said core member at points of tangency to increase the heat transfer area exposed to said high pressure air circulating through said shell.

3. In a gas turbine power plant including a source of high pressure air, a turbine blade construction comprising a metallic shell having a typical blade shape on its outer face, a central metallic core member extending within the shell and spaced from the inner surface thereof, means securing said shell to said core member, means on said core member constructed and arranged for engagement with a turbine wheel in radially extending relation thereto, passage means in said core member to conduct part of said high pressure air into the inner end of said metallic shell, means providing an air escape opening in said shell, and said means securing the shell to the core member including a multiplicity of metallic spheres arranged within the shell bonded to each other, to the shell, and to the core member whereby a filling is provided in said shell porous to the flow of air therethrough to greatly increase the heat transfer area therein.

HEINZ E. SCHMITT.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,550,185	Steenstrup	Aug. 18, 1925
1,893,330	Jones	Jan. 3, 1933
1,966,104	Noack	July 10, 1934
2,440,069	Bloomberg	Apr. 20, 1948
2,448,315	Kunzog	Aug. 31, 1948
2,520,373	Price	Aug. 29, 1950

FOREIGN PATENTS

Number	Country	Date
22,028	Great Britain	Nov. 1, 1901
346,599	Germany	Jan. 5, 1922
584,580	Great Britain	Jan. 17, 1947
602,530	Great Britain	May 28, 1948