Oct. 14, 1952 W. R. HAWTHORNE 2,613,909

TURBINE AND COMPRESSOR BLADING IN AXIAL FLOW INTERNAL-COMBUSTION TURBINE POWER PLANTS

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FIG. 1.

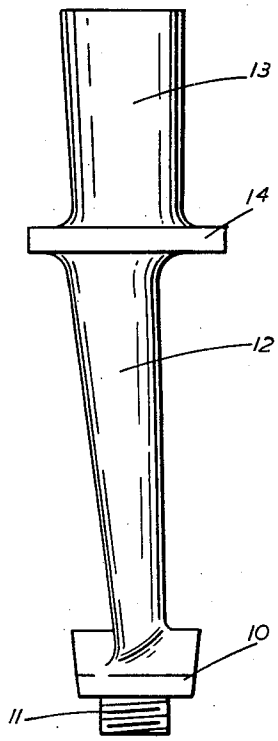
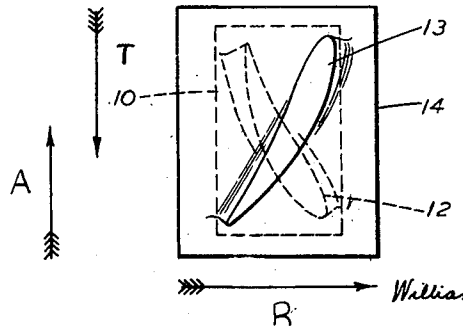



FIG. 2.




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FIG. 3.

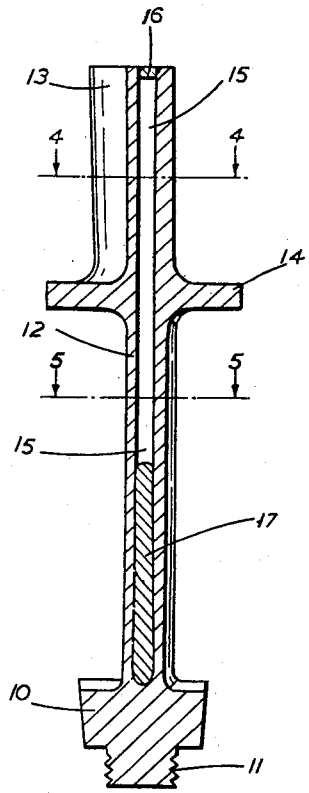



FIG. 4.

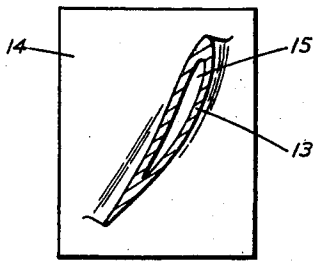
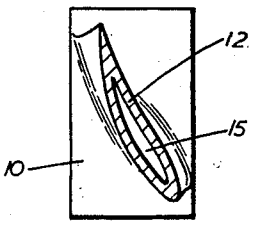



FIG. 5.




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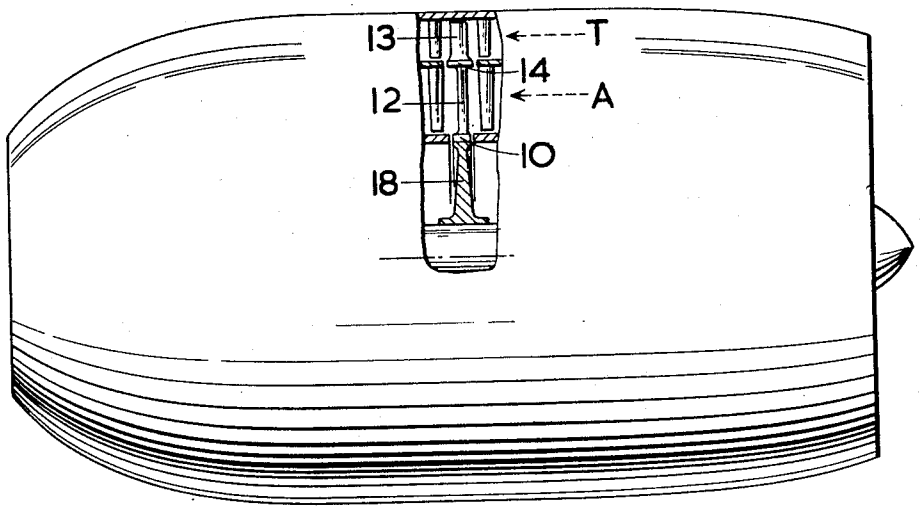



Fig. 6

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2,613,909

## TURBINE AND COMPRESSOR BLADING IN AXIAL FLOW INTERNAL-COMBUSTION TURBINE POWER PLANTS

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10 Claims. (Cl. 253—39.15)

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This invention relates to rotor blading of gas turbines and similarly bladed fluid flow machines in which the working temperature of the blades constitutes a limiting factor in the operation of the machine.

An object of the invention is to provide an improved form of blading for machines of the kind referred to, having improved properties as regards cooling, by providing means whereby heat extracted from the blade part proper, subjected to the working temperature is effectively transferred to another part of the structure, which acts as a heat dissipating means.

According to the present invention there is provided, in or for a machine of the kind referred to and especially a combustion gas turbine, rotor blading of which a blade part proper which lies in the working fluid channel of the machine is associated with an extension part which extends, or in effect extends, the blade structure beyond a boundary of said channel into a cooler zone, said blading having common both to its blade part proper and to its extension part a closed internal cavity containing a suitable coolant medium selected to be convective in the conditions of operation and the relative location of said blade and extension parts, having regard to the arrangement of the blade as a whole, being such as to provide conditions in which a convective circulation of the coolant will be set up due to the temperature differential between said parts. In specifying in the foregoing that the coolant should be convective in the conditions of operation, it is intended to indicate that it should be or should become fluid and capable of circulating flow. In the preferred form, however, it is contemplated that the coolant will be selected to boil in the blade portion and to be condensed in the extension part, so that the convective circulation of the coolant will involve a continuous cycle of evaporation in the blade portion and condensation in the extension part.

It is intended that in use centrifugal force will supersede gravity in determining the location of the coolant in its cavity and will in fact be an important factor in producing the convective circulation desired in a particularly effective manner, as will be more fully explained. Accordingly, the invention contemplates that the portion of the cavity in the extension part referred to will lie radially inwards of the portion in the blade part proper so that the coolant will be centrifuged into the blade part proper in use.

The invention owes its conception to the requirements of, and has particular application to, the cooling of the rotor blading in an axial flow

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gas turbine power plant comprising an axial flow compressor system, coaxially nested within an axial flow turbine system and employing two-tier combined turbine and compressor blading having a radially inner part of compressor profile and a radially outer part of turbine profile. The invention will accordingly be described in detail with reference to the accompanying drawings in relation to such a plant without prejudice, however, to the scope of the appended claims.

In the drawings—

Figure 1 is a view in elevation of a two-tier blade for a combined compressor and turbine of the axial flow type.

Figure 2 is an end view of the same looking towards the root.

Figure 3 is a sectional elevation of the same.

Figures 4 and 5 are views in section taken along the lines 4—4 and 5—5 of Figure 3.

Figure 6 is a diagrammatical view in axial section of a gas turbine power unit of the type employing two-tier blades.

The blade shown in Figure 1 comprises a root portion 10, a blade element 12, a shroud portion 14 and a further blade portion 13, all integrally formed. The root portion 10 includes an extension 11 with serrated or ridged flanks adapted to be secured in a correspondingly formed groove or slot in a rotor drum or wheel.

The blade portion 12 is formed of appropriate profile and angle to act as part of a row of axial flow compressor blading. Similarly, the blade portion 13 is appropriately formed to act as part of a row of axial flow turbine blading.

In Figure 1 the composite blade is viewed in the axial direction of the turbocompressor, of which it is to form part, and in Figure 2 the direction of rotation is indicated by an arrow R. Arrows A and T, respectively, indicate the directions of flow of air and gas through the compressor and turbine respectively, the compound blade of the example illustrated being intended for a turbo-compressor combination operating on the contraflow principle. For a turbocompressor combination in which turbine and compressor flow is in the same direction, a composite blade, according to the invention would be generally similar to that illustrated but with the blade angles of the two blade portions 12—13 appropriately altered.

It will be noticed that the turbine portion 13 of the composite blade is disposed outwardly of the compressor portion 12 (with respect to the axis of rotation). For reasons to be hereinafter explained this disposition is an important fac-

tor in the effective operation of a cooling system according to the invention.

The composite blade is formed hollow as shown in Figures 3 to 5, a cavity 15 in the interior of the blade extending from the root 10 to the extremity, where it is closed by a plug 16. This hollow 15 is partially filled with an appropriate high temperature cooling medium indicated at 17. This medium is inserted into the hollow 15 during manufacture before inserting and permanently securing the plug 16.

The material used for the filling 17 may be metallic sodium or a suitable salt of relatively high melting point such as is used as an internal coolant for the exhaust valves of poppet valve reciprocating internal combustion engines, and the amount of the filling 17 should be such that when it is cold, and therefore in the solid state it should occupy less than half of the total volume of the internal space 15 of the composite blade.

The above-described two-tier hollow blade when assembled in the complete machine appears as revealed in Fig. 6 by the cutting away of the casing of the machine, the blade root 10 being secured to the rim of a conventional form of rotor wheel 18. The inner compressor portion 12 of the blade lies in the channel for air flowing as indicated by the arrow A while the turbine portion 13 of the blade lies in the outer channel for hot gas flowing in the same direction as the air as indicated by the arrow T.

The heat is conducted inwards along the blade of the inner blade portion 12, the temperature of which rises sufficiently to melt the sodium or salt filling 17. The latter is thereupon flung outwards by centrifugal force to the outer end of the hollow 15 where it is in heat conductive contact with the walls of the turbine portion 13 of the blade. As the temperature of the liquid sodium or salt rises by conduction from the hot walls of the blade portion 13 the vapour pressure rises and the concentration of vapour in the inner end of the hollow 15 in contact with the walls of the inner compressor blade portion 12 is increased. Heat received by the liquid sodium or salt from the walls of the turbine blade portion is transferred by the vapour to the walls of the compressor blade portion. On account of its latent heat vaporisation, the liquid sodium or salt is capable of receiving and transferring a large amount of heat with a comparatively small rise of temperature, the heat transferred being promoted by convection currents in the liquid and vapour phases of the cooling medium, which thus cools the hot turbine part 13 of the blade very efficiently and by transferring the heat to the cooler compressor part 12 of the blade, helps to reduce the temperature gradient within the material of the blade itself and thus to minimise internal stresses and liability to distortion.

The heat dissipated from the walls of the compressor part 12 of the blade by conduction or radiation is taken up by the charge passing through the compressor and is therefore not entirely lost. With a contra-flow arrangement of turbine and compressor the transfer of heat is to some extent regenerative.

In order to obtain perfect balance of the turbo-compressor rotor incorporating blades according to this invention, it is necessary not only that the blades shall be in perfect balance without their filling of cooling medium but that precisely the same weight of cooling medium be introduced into each blade. It is also important that the hollows 15 of the several blades be dimensioned to fine limits in order that the centres of gravity of the fillings 17 when liquid and centrifuged to the outer ends of the hollows 15 shall be equidistant from the axis of rotation.

It is essential that the plugs 16 be adequately secured to withstand the centrifugal force of the liquid fillings 17.

It will be recognized that in the construction illustrated in and described with reference to the drawings, the inner (compressor) portion 12 of the blade constitutes, in principle, merely a radially inward extension of the outer (turbine) portion 13, beyond the confines of the hot gas duct in which the part 13 will operate in use, into a cooler zone represented by the compression duct, its compression function being incidental to the main purpose of cooling. It will also be appreciated, that, although the invention has been described in its application to blades extending radially outwardly from an inner rotor, the basic requirement called for by the invention as regards disposition is merely that the coolant chamber should afford, for the circulation of the coolant, a path having a radially outward component from the cooler extension part of a blade to the blade part proper.

What I claim as my invention and desire to secure by Letters Patent is:

1. A turbine or similarly bladed fluid flow machine required to run at high temperatures and especially a combustion gas turbine, comprising a rotor blading each blade of which includes a blade part proper disposed in the working fluid channel and an extension part having a blade formation which projects into and in effect extends the blade structure beyond a boundary of said channel into a cooler zone which includes a fluid flow channel, each said blade having common both to its blade part proper and to its extension part a closed internal cavity containing a coolant medium only partly filling same and convective in the conditions of operation and said cavity being arranged so that the coolant medium will be centrifuged into the blade part proper in use, the arrangement being such that due to the relative location of said blade and extension parts, their differential temperature and the centrifuging of the coolant medium, conditions are provided in which a convective circulation of the coolant will be set up in use, and means to maintain a flow of cooling medium through said fluid flow channel.

2. A gas turbine embodying an axial flow compressor coaxially nested within an axial flow turbine, having two-tier blading extending outwardly in the radial sense from an inner rotor each blade of which includes a blade part proper acting as turbine blading disposed in the working fluid channel and a radially inner extension part acting as compressor blading which projects into and in effect extends the blade structure beyond an inner boundary of said channel, each said blade having common to both its blade part proper and to its extension part a closed internal cavity containing a coolant medium only partly filling same and convective in the conditions of operation, the arrangement thus being such that due to the relative location of said parts, their differential temperature and the centrifuging of the coolant medium, conditions are provided in which a convective circulation of the coolant will be set up in use.

3. A rotor blade designed and adapted for use in a turbine or similarly bladed fluid flow machine required to run at high temperatures and

especially a combustion gas turbine and comprising, in addition to a blade part proper intended in use to be disposed in the working fluid channel, an extension part having a blade formation which is intended in use to project into and in effect extend the blade structure beyond a boundary of said channel, said blade having common both to its blade part proper and to its extension part a closed internal cavity containing a coolant medium only partly filling same and convective in the conditions of operation and said cavity being arranged so that the coolant medium will be centrifuged into the blade part proper in use, the arrangement being such that due to the relative location of said blade and extension parts and the centrifuging of the coolant medium conditions are provided in which a convective circulation of the coolant will be set up in use if said extension part is kept at a lower temperature than said blade part.

4. A two-tier combined turbine-compressor blade designed and adapted for mounting on the inner rotor of a turbine having blading extending outwardly in the radial sense from an inner rotor and comprising in addition to a radially outer blade part proper designed to act as an axial flow turbine blade intended in use to be disposed in the working fluid channel, an extension part designed to act as an axial flow compressor blade which lies radially inwardly of said blade part proper and is intended to extend beyond an inner boundary of said channel in use, said blade having common both to its blade part proper and to its extension part a closed internal cavity containing a coolant medium only partly filling same and convective in the conditions of operation, the arrangement thus being such that due to the relative location of said blade and extension parts, having regard to the intended arrangement of the blade as a whole in use and the centrifuging of the coolant that will then take place, conditions are provided in which a convective circulation of the coolant will be set up in use if said extension part is kept at a lower temperature than said blade part.

5. A combined turbine-compressor blade as claimed in claim 4 including an integral shroud portion, adapted to form part of a complete shroud ring in the assembled engine and located between the turbine and compressor tiers of the blade, the mentioned internal cavity passing through the said shroud portion.

6. A turbine or similarly bladed fluid flow machine required to run at high temperatures and especially a combustion gas turbine, comprising radially extending rotor blades, each said blade including a radially outer blade part proper lying in the working fluid channel of the machine, a radially inner extension part extending beyond said channel into a cooler zone radially within it, said parts of the blade having a common closed internal cavity, and a coolant medium partly filling said cavity, said medium being selected to be liquid at the temperature of the extension part and vapor at the temperature of the blade part proper in operation, whereby a convective circulation of the coolant medium is set up in the cavity due to the combined effects of centrifuging and the different temperatures of said parts of the blade.

7. A turbine or similarly bladed fluid flow machine required to run at high temperatures and especially a combustion gas turbine, comprising means defining an annular channel for working



fluid and a further channel lying radially within said first-mentioned channel, means for maintaining a flow of cooling fluid through said further channel, radially extending rotor blades, each said blade including a radially outer blade part proper lying in said working fluid channel, a radially inner extension part lying in said further channel, said parts of the blade having a common closed internal cavity, and a coolant medium partly filling said cavity, said medium being selected to be liquid at the temperature of the extension part and vapor at the temperature of the blade part proper in operation, whereby a convective circulation of the coolant medium is set up in the cavity due to the combined effects of centrifuging and the different temperatures of said parts of the blade.

8. A gas turbine plant comprising an axial flow turbine, an axial flow compressor having its annular air flow channel nested coaxially within the annular gas flow channel of the turbine, and radially extending two-tier rotor blades, each said blade including a radially outer part of turbine blade formation lying in the gas flow channel of the turbine, a radially inner part of compressor blade formation lying in the air flow channel of the compressor, said parts having a common closed internal cavity, and a coolant medium partly filling said cavity, said medium being selected to be liquid at the temperature of the compressor part of the blade and vapor at the temperature of the turbine part of the blade in operation, whereby a convective circulation of the coolant medium is set up in the cavity due to the combined effects of centrifuging and the different temperatures of said parts of the blade.

9. A rotor blade for a turbine or similarly bladed fluid flow machine required to run at high temperatures and especially a combustion gas turbine, comprising a blade part proper intended to lie in the working fluid channel of the machine and an extension part intended to extend beyond said working fluid channel into a cooler zone radially within it, said part having a common closed internal cavity, and a coolant medium partly filling said cavity, said medium being selected to be liquid at the temperature of the extension part and vapor at the temperature of the blade part proper in operation, whereby a convective circulation of the coolant medium is set up in the cavity due to the combined effects of centrifuging and the different temperatures of said parts of the blade.

10. A two-tier rotor blade for a gas turbine plant comprising an axial flow turbine and an axial flow compressor having its annular air flow channel nested coaxially within the annular gas flow channel of the turbine, including a part of turbine blade formation intended to lie in the gas flow channel of the turbine, a part of compressor blade formation intended to lie in the air flow channel of the compressor, said parts having a common closed internal cavity, and a coolant medium partly filling said cavity, said medium being selected to be liquid at the temperature of the compressor part of the blade and vapor at the temperature of the turbine part of the blade in operation, whereby a convective circulation of the coolant medium is set up in the cavity due to the combined effects of centrifuging and the different temperatures of said parts of the blade.

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