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TURBINE WHEEL AND BLADE CONSTRUCTION

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Fig. 1.

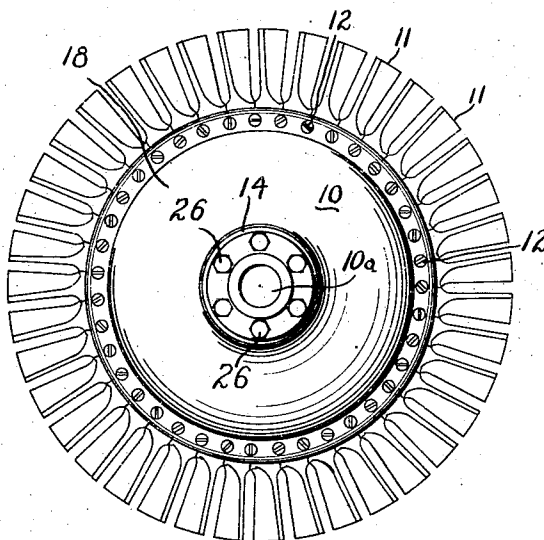
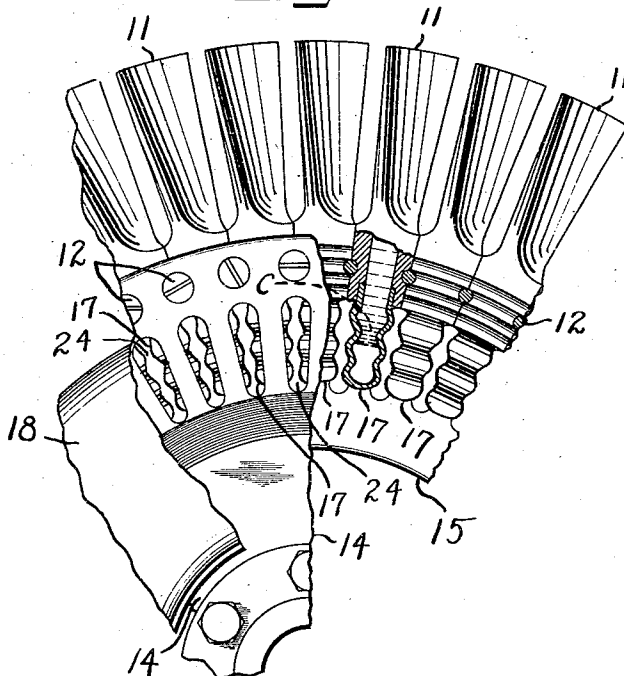


Fig. 2.



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TURBINE WHEEL AND BLADE CONSTRUCTION

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My invention relates to the cooling of rotating devices, such as, for example, the blades used in superchargers, jet turbines, gas turbines, and the like.

The blades of gas turbines, superchargers, jet turbines, and the like are subjected to very high temperatures by the working fluid, such as burning gases, acting thereagainst. While highest operating efficiency may be obtained with the hottest working fluids, known blade metals cannot be heated to the temperature of such efficient fluids without excessive distortion, and early failure under the stresses imposed thereon. Therefore, the maximum temperature of the gas or other working fluid acting upon the blades has heretofore been limited by the heat resistance properties of the blade metals.

According to this invention more efficient and hotter working fluids can be used without damaging the blades by improving the heat dissipating properties of the blades especially along the radial lengths of the blades. This increases the temperature gradient at the surface of the blades and thus decreases the blade temperature as compared to the temperature of the working fluid.

It is an object of my invention to provide an improved rotating element for turbine blades, and the like, wherein more effective heat transfer from the outermost portion to the innermost portion is obtained.

Another object of my invention is to provide an improved element for use in a rotating structure having good heat transfer in the radial direction while at the same time avoiding the need for piping or other additional apparatus.

Also it is an object of my invention to provide an element for use in rotating structures having a high degree of heat transfer in the radial direction and which is adapted for use in superchargers, jet turbines, gas turbines and the like.

Another object is to provide a hollow turbine bucket for jet engines and the like.

Further it is an object of my invention to provide a coolant filled hollow turbine blade wherein centrifugal action inherent in the rotational motion thereof acts to supplement the natural forces causing convection currents in the coolant and hence improves the cooling action.

Still another object of my invention is to provide an improved blade for use in gas turbines and the like which is effective even though one side of the blade tends to be heated to a greater extent than the other side thereof.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings.

On the drawings:

Figure 1 is an elevational view of a gas turbine wheel and blade assembly constructed in accordance with the principles of my invention;

Figure 2 is an enlarged elevational view of a portion of the gas turbine wheel and blade assembly of Fig. 1, portions thereof being shown in section;

Figure 3 is an enlarged axial section of the blade and wheel structure of Figure 1;

Figure 4 is an axial section of an alternate embodiment of the structure of Figure 1;

Figure 5 is an alternate construction of the blade for use in the structure of Figure 1; and

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Figures 6 and 7 show still another embodiment of the blade for use in the structure of Figure 1.

As shown on the drawings:

Figure 1 shows the construction of a turbine wheel embodying the features of my invention as viewed in the axial direction. This structure consists of wheel portion, shown generally at 10, attached by bolts 26 to shaft 10a to rotate therewith and on which a plurality of blades 11 are mounted. As shown more clearly in Figure 3, these blades have root ends with superimposed stepped notches 13 in the front and rear faces thereof to coact with similar notches in the two flanges 14 and 15 constituting wheel 10. The blades 11 are securely fastened to flanges 14 and 15 by means of bolts 12 which are equally spaced about the periphery of the wheel as shown in Figure 1.

In accordance with my invention blade 11 is hollow and has a recess 16 therein, extending in the radial direction therethrough and varying in size in accordance with the blade structure so as to provide walls thereof of sufficient thickness to support the stresses imposed by the force of the gas impinging on the blade. This radially inner or root end of the recess is in communication with the interior of a cooling bulb 17. This bulb 17 is preferably constructed of copper and brazed into the root end of the blade. The blade is composed of high heat alloy metal and copper is particularly suitable for the brazing metal because of its good thermal conductivity. The bulb 17 depends radially from the inner or root end of the blade.

As will be described in further detail hereafter, the recess 16 is filled with coolant C such as sodium to increase conduction of heat from the hot outer periphery to the cooler bulb 17 and thereby limit the temperature of the blade 11 in the regions exposed to the hot blast of the working fluid.

Cooling of bulb 17 is preferably achieved by a blast of air or other fluid thereacross. Figure 3 shows an axial cross-section of one structure for supplying this cooling medium, this structure including shield 18 which is arranged to guide cooling medium from a region of small radius outwardly to the portion of the flanges 14 and 15 immediately below the blade 11 and communicating with cooling bulb 17. At this point, the fluid passes across cooling bulb 17 and is discharged in the axial direction. Ports 24 in flange 14 and ports 25 in flange 15 are provided to register with the space between each pair of adjacent bulbs 17 to permit cooling fluid to flow over the bulb walls. These walls are preferably corrugated to increase the surface area thereof. Figure 2 shows a cross-sectional view of the turbine wheel with the shield 18 removed. It will be observed that sufficient space is provided between adjacent cooling bulbs 17 to permit the flow of cooling medium therebetween.

In the operation of the above-described turbine wheel and blade construction, the outwardly extending portions of blade 11 are exposed to the high temperature working fluid which in the case of a turbo-supercharger is the hot exhaust gas from the connected reciprocating engine and in the case of a jet turbine is the heated air-gas mixture constituting the working fluid. This fluid, in passing across the outermost portion of blade 11 (designated as 11-a in Figure 3) heats the blade 11. This causes heat flow through the blade walls to the coolant C such as sodium contained therein, thus increasing the temperature thereof and causing liquefaction of the entire mass of material within the recess. Further, heat transfer due to the presence of the hot gases flowing past the outer periphery of blade 11 causes the sodium at the outermost portion to become less dense and hence produce a smaller pressure due to centrifugal forces than would exist at lower temperature. Inasmuch as the fluid pressure in all directions is identical, this causes the heavier, lower temperature, sodium from the portions of the blade having smaller radius, to be forced outwardly and the hotter, low density, sodium at the outermost portion of the blade to be forced inwardly. Hence a fluid flow is set up as shown by the arrows of Figure 3. When the fluid reaches bulb 17, the cooling air or other fluid passing across the surface thereof tends to cause heat transfer therefrom. Since this heat must be taken from the fluid contained

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within the bulb 17, that fluid is cooled and becomes more dense, thereby causing increased pressure by reason of the centrifugal acceleration thereof and thus causing outward flow toward the extended portion 11a of the blade.

The rate of circulation of the sodium contained within the recess 16 and cooling bulb 17 is very great by reason of the large centrifugal forces associated with rotation of the turbine wheel as compared with the circulation that would be achieved in the presence of gravity alone. In this respect, the direction of flow of the cooling medium is contrary to the direction that would be anticipated inasmuch as the fluid contained in the portions having maximum radial distance and hence greatest centrifugal force are forced inwardly against the centrifugal acceleration to cooling bulb 17. As is well known, this rapid fluid flow not only causes the heat to be transferred from the outermost portion of the blade 11 to the innermost portion of bulb 17 at a rapid rate but also, by reason of the relative motion against the inner surfaces of recess 16 and bulb 17, improves the heat transfer therebetween so that an efficient and effective cooling action is obtained. Inasmuch as this cooling action tends to cause the bulb portion 17 to assume the temperature of the outer portion 11a of blade 11, the cooling medium passing by bulb 17 is exposed to a surface having relatively high temperature. Since the amount of heat energy passed from the surface of bulb 17 to the cooling medium is dependent on the temperature difference therebetween, this relatively high temperature of the cooling bulb 17 thus increases the rate of heat transfer to the cooling fluid, thereby increasing the rate of heat transfer from the blade portion 11-a to the cooling fluid. As is well known, the increased rate of heat transfer causes a corresponding increased temperature gradient between the working fluid to which blade 11-a is exposed and the blade itself, thereby reducing the blade temperature relative to the temperature of the working fluid and enabling a greater temperature of the latter without causing undesired weakening, creep, or fatigue of the blade material.

Figure 4 shows an alternative embodiment of a turbine wheel and blade constructed in accordance with our invention. As shown in this figure, the flange 14a is made solid and cooling air applied to bulb 17 through the annular opening between this flange and flange 15 which has an opening 25 suitable for passage of cooling air.

A further alternative blade construction is shown in Figure 5. In this construction the root end of the blade, shown generally at 19, is extended radially inward to provide an integral portion for taking the place of bulb 17. This portion has spaced parallel grooves 20 along the side faces thereof to provide fins therebetween which will be exposed to the air passing through the ports 24 and 25 of the wheel. These grooves may be milled along the surface of the lower end of the blade, a machine operation that can readily be conducted in the mass production of the blade, thereby achieving minimum manufacturing costs thereof. The increased surface area exposed to the cooling medium by reason of the grooves or slots 20 causes a corresponding increased heat transfer thereto and thus enables the innermost portion of the blade to transfer considerable heat notwithstanding the fact that it cannot easily be constructed of high heat conductivity material such as the copper of cooling bulb 17.

Figures 6 and 7 show a further alternative construction of the blade 11 intended for use where the flow of the working fluid past one side of the blade tends to cause greater heat transfer thereto than the other side. In this construction, baffle 21 extends along the length of the blade to separate the portions of the blade tending to heat to the greatest degree from the other portions thereof. An opening is provided between the top of baffle 21 and the most extended portion of blade 11 and between the bottom of baffle 21 and the lowermost portion of cooling bulb 17 so as to provide a continuous passageway for the cooling medium as shown in Figure 6. Figure 7 shows the structure of baffle 21 and blade 11 as seen from cross-section VII-VII, Figure 6. As will be evident from Figure 7, the baffle extends entirely across the blade structure so as to provide two distinct passageways in the radial direction, one for outward flow of sodium and the other for inward flow thereof.

In the operation of the embodiment of my invention shown in Figure 6, one side of the blade 11, say, the left side as seen in Figure 6, tends to have greatest heat transferred thereto, as, for example, by reason of the di-

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rection of flow of the working fluid. This heat causes the sodium or other medium contained therein to increase in temperature, thereby becoming less dense and being forced inwardly by reason of the greater centrifugal pressure exerted by the more dense fluid in the other portion of the blade. This produces a continuous circulation of fluid in the counterclockwise direction as seen in Figure 6, thereby providing effective cooling action. In the embodiment of my invention shown in Figures 6 and 7, it will be observed that the fluid flows in a continuous path without eddy currents or other influences tending to increase the fluid friction and hence decrease the rate of flow, thus providing a maximum degree of cooling action.

Figures 3 and 4 show one method of constructing blade 11. In accordance with this method, a suitable opening is provided in the lower portion of cooling bulb 17, this opening being designated as 22 in the figures. In the manufacture of the blade, metallic sodium is passed through this opening into the blade until the level of the sodium is such that only a small air space is left therein, this space being only sufficient to accommodate the increased volume of the sodium as the temperature is raised. The opening 22 may then be closed by welding a plug thereto, thus sealing the unit for operation. In the blade of Figure 6, the opening 23 is provided in the end of blade 11 and the plug welded thereto after filling the recess 16 with sodium.

It will be observed that I have provided a self-contained hollow turbine blade having inherently good cooling properties when operating and taking advantage of the centrifugal acceleration incident to turbine operation. Furthermore, the spent cooling fluid is passed in an axial direction from the wheel and may conveniently be combined with the exhaust working fluid to be ejected from the unit. This is in marked contrast to previous attempts to cool turbine blades by means of a cooling fluid as such attempts have required extensive piping systems and have entailed considerable energy losses in the required pumping.

A further feature of the blade structure of Figures 1, 2 and 3 and the modification of Figure 4 resides in the fact that the functions of cooling and blade operation are separated, the former function being confined to the cooling bulb 17 and the latter being confined to the blade portion 11. Thus, blade portion 11 may be constructed of material having a high degree of resistance to creep, fatigue, and weakening at the high temperatures induced by the exposure to the working fluid whereas cooling bulb 17 may be made of copper or other material having good thermal conductivity but poor mechanical characteristics at the high temperatures of the blade portion 11.

The recess 16 provided in the turbine blades has only slight effect on the ability thereof to withstand the forces associated with turbine operation. As is well known, the blades act as cantilever beams in communicating the force of the working fluid to the wheel and the material close to the neutral axis thereof provides little strength. Thus, the recess 16, located in the inner portions of the blade, reduces the strength thereof to only a minor degree.

While I have described my invention with particular reference to a gas turbine such as might be used in a turbo-supercharger, it will be understood that its applications are not limited thereto and that it may be applied to all elements mounted on rotating structures which tend to be heated at their outer portions and it is desired to remove this heat by means of a heat flow from their inner portions.

It will, of course, be obvious to those skilled in the art that material other than sodium may be contained within the recess 16 of the turbine blade, the principal requirements for such material being that it have substantial decrease in density with temperature and good heat conduction characteristics.

While I have shown particular embodiments of my invention, it will, of course, be understood that I do not wish to be limited thereto as many modifications both in the elements employed and their cooperative structure may be made without departing from the spirit and scope of my invention. I, of course, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope thereof.

I claim as my invention:

1. A turbine comprising in combination, a wheel including two axially spaced flanges, a blade having a hollow working portion extending radially outside of said

flanges to contact a high temperature working fluid to develop turbine operating force, said blade having a fastening portion between said flanges for cooperation therewith to rigidly maintain said blade in position in said turbine wheel, said blade having a hollow heat-transfer bulb portion extending radially inwardly from said fastening portion into a hollow air space between said flanges, said flanges being slit at intervals to allow axial passage of air into said hollow air space, means for supplying air at a positive pressure to said slits, said bulb portion comprising a material having an extremely high thermal conductivity, while said blade comprises a metal having great heat resistance, and a fluid medium within said bulb and said blade, said medium having a decreasing density with increase in temperature whereby operation of the turbine blade in high temperature working fluids will cause a convective current in the cooling medium from the working portion of the blade to the bulb due to density changes which cause movement due to the action of centrifugal force.

2. A turbine comprising in combination, a wheel including two axially spaced flanges, a blade having a working portion and a root portion, said root portion including blade anchoring means in operative engagement with the outer peripheries of said flanges, and said working portion extending radially outwardly from said root portion and said flanges to contact a high temperature working fluid to develop turbine operating force, said blade having a hollow extension portion extending radially inwardly from said root portion into the space between said flanges, said working portion having a recess therein communicating through said root portion with the hollow interior of said extension portion and defining therewith a closed cavity within the blade, at least one of said flanges having holes for the escape of fluid from the region about said extension portion, and means to introduce cooling fluid between said flanges to cause escape thereof through said holes to cool said extension portion of said blade, and a fluid medium having decreasing density with increase in temperature at the temperature of normal operation contained within said recess and said extension portion, thus to set up fluid flow tending to transfer heat from said working portion to said extension portion.

3. A turbine according to claim 2 wherein said blade extension portion is provided with external fins.

4. In a turbine rotor and blade assembly including a rotatable turbine wheel having a periphery for anchoring the roots of blades and a passage radially inward from said periphery for flow of cooling fluid therethrough, the improvement of a blade having a root portion anchored in said periphery of the turbine wheel, a vane portion extending radially outward from the periphery of said turbine wheel and a cooling bulb portion extending radially inward from said root portion across said passage of the turbine wheel, said vane portion adapted to be exposed to high temperature working fluid for producing operating forces to rotate said wheel, said cooling bulb being exposed to cooling fluid in said passage of the turbine wheel, said vane portion being constructed of high temperature resisting material, said bulb portion being constructed of high thermal conductivity material, said vane portion having a recess therein communicating with the interior of said cooling bulb, and a fluid medium having decreased density with increased temperature in the normal range of operating temperatures contained within the recess whereby rotation of the turbine wheel together with the heating of the vane portion of the blade by the working fluid sets up fluid flow in said recess causing a transfer of heat from the vane portion to said cooling bulb and a transfer of heat from the cooling bulb to a cooling fluid in said passage of the turbine wheel.

5. A turbine comprising in combination a wheel having a peripheral rim and a hollow air space inwardly from said rim, means for circulating cooling air through said air space, a blade having a working vane portion extending radially outward from said rim of said wheel, an anchoring root portion anchored in said rim of the wheel and a bulb portion extending radially inward from said rim across said hollow air space, said working vane portion of the blade adapted to contact a high temperature working fluid to develop turbine operating force for rotating said wheel, said blade having a cavity extending from the bulb portion through the vane portion, a fluid medium having decreased density with increased temperature at the temperature of normal operation of

said blade contained within said cavity, and means to direct a stream of cooling air through said hollow air space and around the bulb portion to reduce the temperature of the bulb portion whereby heating of said fluid medium in the vane portion of the blade will decrease the density of the medium in the vane portion and whereby rotation of the wheel will create a centrifugal force transferring the heavier fluid medium from the bulb portion to displace the heated fluid medium of decreased density in the vane portion and whereby the cooling fluid will cool the bulb portion to decrease the temperature of the heated fluid medium in the bulb thereby increasing its density and setting up fluid flow transferring heat from the vane portion to prevent overheating of the vane portion by the working of fluid.

6. In a turbine wheel having a rim portion, a cooling space inwardly from said rim portion and means for circulating cooling air through said space, the improvement of a hollow turbine blade having a vane portion extending radially outward from the rim portion of the wheel, a root portion anchored in the rim portion of the wheel and a cooling bulb portion extending into the cooling space to be cooled by air flowed therethrough, a fluid medium in said blade having decreased density with increased temperature, a baffle in the vane portion of said blade dividing the vane cavity into two communicating compartments including a compartment on one side of the baffle tending to be heated by the working fluid for driving the turbine to a greater degree than the compartment on the other side of the baffle whereby fluid currents are set up in said blade along the length of the blade by the change in density of the cooling medium as it is heated and by the centrifugal forces associated with rotation of the turbine to effect heat transfer from the vane portion to the bulb portion, and said cooling air in the cooling space being effective to dissipate heat from the bulb portion.

7. In a turbine wheel assembly including a wheel having blade anchoring means around the periphery thereof and a cooling space inwardly from the periphery, the improvement of a hollow turbine blade having a working vane portion extending radially outward from the periphery of the wheel, an anchoring root portion secured in the periphery of the wheel and a heat transfer portion extending radially inward from the anchoring root portion across the cooling space, said vane portion having a longitudinally extending recess communicating through the root portion with the hollow interior of the heat transfer portion, a coolant in said recess adapted to transfer heat from the vane to the heat transfer portion, said coolant decreasing in density with an increase in temperature whereby hot working fluid acting on said vane portion to drive the turbine will decrease the density of the coolant in the vane portion whereupon rotation of the turbine will centrifugally discharge heavier cool coolant from the cooling portion of the blade into the vane portion for replacing the heated coolant to create a flow of coolant along the length of the blade, and means for flowing a cooling medium through the cooling space of said turbine for conducting heat from the heat transfer portion of the blade in the cooling space.

8. A turbine wheel assembly comprising a wheel having blade anchoring means around the periphery thereof, a plurality of turbine blades having root portions anchored in said blade anchoring means, vane portions extending radially outward from said root portions and heat transfer portions extending radially inward from said root portions, said blades being hollow and each having a cavity extending from the heat transfer portion through the root portion into the vane portion, said wheel having a cooling space inwardly from the periphery, said heat transfer portion of the blades extending across said cooling space, means for circulating a cooling fluid through said space to flow around said heat transfer portions of said blade to dissipate heat therefrom, and a coolant in the cavity of each blade adapted to decrease in density with an increase in temperature to establish a circulation of heated coolant from the vane portion to the heat transfer portion as the wheel assembly is rotated.

9. A turbine and blade assembly for a gas turbine engine required to run at high temperatures which comprises a turbine wheel having a rim portion adapted to anchor a plurality of turbine blades and a heat transfer chamber inwardly from said rim portion, hollow turbine blades disposed radially around the periphery of said

wheel and having anchoring roots secured in said rim portion, vanes extending radially beyond the rim portion and heat transfer portions extending radially inwardly from the root portion into said cooling space, each blade having a continuous cavity extending from the heat transfer portion through the root portion into the vane portion, a coolant medium in the cavity of each blade adapted to set up a convective current when the vane portions of the blades are heated by working fluid and when the turbine is rotated whereby the vanes will be cooled by the coolant and the coolant will be cooled by the heat transfer portions of the blades.

10. A turbine comprising in combination, a wheel having two axially spaced flanges with outer peripheries defining a rim, a blade anchored between said flanges and having a vane portion extending outwardly from said rim defining outer peripheries of the flanges together with an inner portion extending radially inwardly from said outer peripheries of said flanges into the space between said flanges, said blade being hollow and having a continuous cavity extending through the vane portion to the inner portion thereof, means for circulating a first cooling medium through the space between the flanges inwardly from said outer peripheries of the flanges and around said inner portion of the blade in direct contact therewith, and a second cooling medium having decreased density with increased temperature contained in said

cavity whereby the heating of said second cooling medium by the vane portion of the blade will decrease the density of said second medium in the vane portion while rotation of the wheel will displace the thus heated second medium with cooled and hence heavier portions of said second medium from the inner portion of the blade for setting up flow of the second medium to transfer heat from the blade to the first cooling medium circulating around the inner portion of the blade.

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