Dec. 23, 1958 M. L. MOSESON 2,865,598

AIR COOLED TURBINE WHEEL DESIGN

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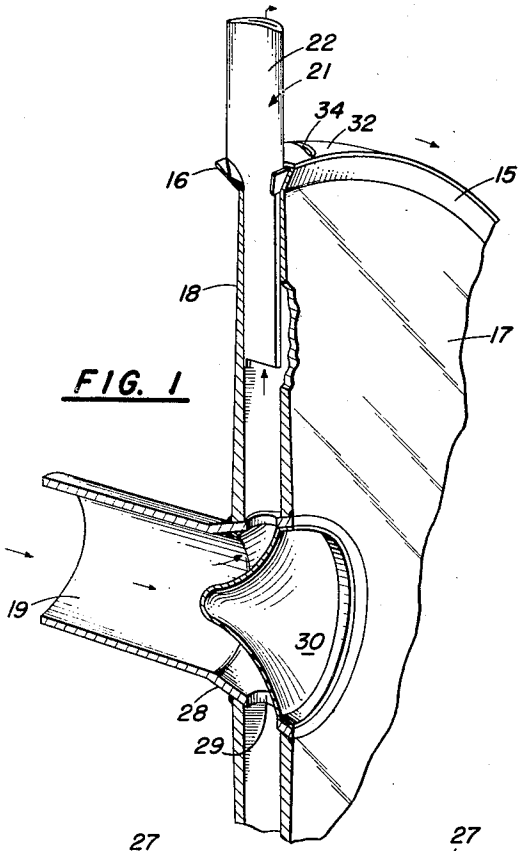


FIG. 1

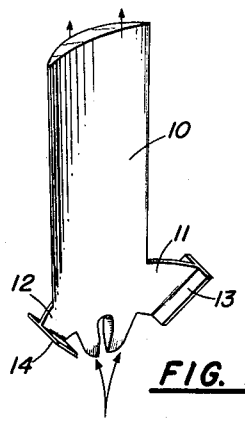


FIG. 2

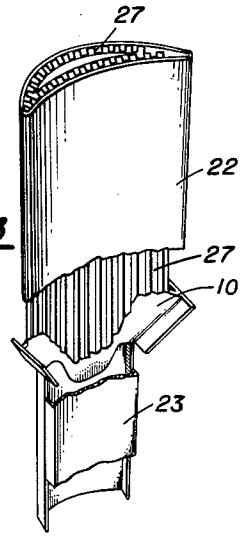


FIG. 3

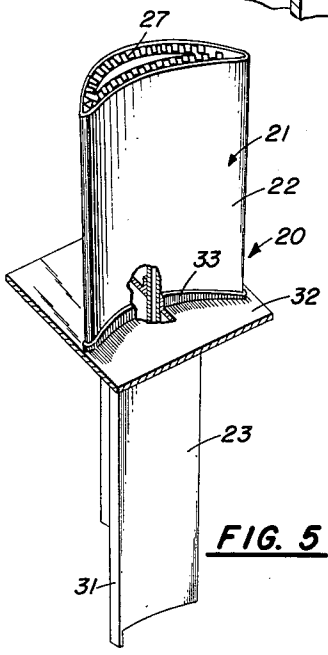


FIG. 5

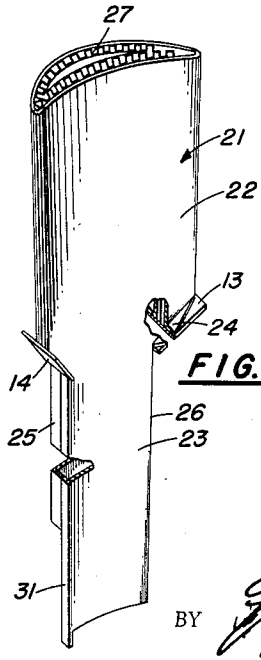


FIG. 4

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AIR COOLED TURBINE WHEEL DESIGN

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This invention relates to an integral turbine blade and turbine wheel construction for utilization in applications where light weight is required and where blade replacement is not a factor to be considered.

In prior art turbine wheel constructions, the turbine blades are forged or cast with an integral blade base or root which forms a platform for the airfoil portion of the blade. The blade base is then broached or machined to form a fir tree, dovetail, or other type of mechanical fastening for attachment to the turbine disk. The turbine disk is forged and a rim forging composed of a heat resisting alloy is welded to the hub portion of the disk. This rim forging of heat resisting alloy is then machined to provide blade fastening slots therein into which the bases of the turbine blades are fitted and suitably attached. The disk and rim forgings are heavy and costly to produce and have the further disadvantage that the interruptions in the outer portion of the rim, into which the blade bases are fitted, causes a great portion of the rim to become a dead load, that is, this outer portion of the rim adds weight to the turbine wheel without providing a corresponding amount of strength to the turbine wheel. Furthermore, the blade bases are objectionable in the same respect because they dictate the use of wide rims on the turbine disks to bring the bearing and shear stresses in the fastening within acceptable limits. The only essential part of the rim load on a turbine disk is caused by the airfoil portions of the turbine blades. Thus, in turbine wheels of conventional design all of the centrifugal load, during operation, which is caused by the blades, blade bases, and the interrupted portion of the rim must be transferred to the disk at the maximum diameter of the uninterrupted portion of the disk. Some of the prior art has proposed the use of hollow, air cooled turbine blades to reduce the weight of the turbine wheel. However, the basic limitations of the interrupted wheel rim and the conventional modes of attaching the blade roots to the wheel rim still exist in the prior art constructions in spite of the weight reduction due to the hollow blades. These factors account for most of the load on the turbine wheel. It is to be further noted in connection with the prior art constructions mentioned above that there are a relatively small number of industrial installations which are capable of making turbine wheel constructions as taught by the prior art.

The present invention proposes to overcome the drawbacks of the prior art by disclosing an integral turbine blade and turbine wheel construction for utilization in applications where light weight is required and where blade replacement is not a factor to be considered. Broadly, the present invention consists of a plurality of light weight air cooled blades having interior heat transfer surfaces formed by corrugations separating the blades from island shaped inserts. The blades are extended down between, and attached to, two light weight circular disks, which form the hub portion of the turbine wheel. A shroud is further provided which fits between the wheel disks and around the turbine blades at the periphery of the disks

for the purpose of sealing the voids at the periphery of the wheel. This particular construction permits weight reduction at the rim of the disk by precluding the need for any interruption of the disk rims. In operation the centrifugal load of the blade is transferred gradually to the disks and this construction provides the further advantage of carrying a portion of the load to the cooler regions of the disk where permissible disk stress levels are higher. The above mentioned island shaped inserts are attached to the disk rims in such a manner as to carry their own loads and part of the load of the above mentioned corrugations to the disks rather than first transferring this load to the above mentioned outer shroud which is one of the hottest members of the assembly. The turbine wheel assembly is provided with cooling air which is fed between the disks through a hollow shaft upon which the assembly is mounted. This cooling air passes radially from the assembly through the above mentioned corrugations and discharges out of the tips of the blades into the main gas stream of the turbine.

It is accordingly one object of this invention to disclose a turbine wheel which is much lighter than any known design of equivalent tip diameter or capacity.

It is a further object of this invention to disclose a turbine wheel wherein the centrifugal load from a set of blades is gradually transmitted to the disk portion of the wheel at various radial positions on the wheel disks without interrupting the rim circumference of the disks. In this manner some of the load is transmitted to cooler central portions of the disks where higher stresses are permitted.

It is another object of this invention to obviate the necessity of having thick turbine disk rims to accommodate the shear and bearing stresses of conventional blade fastenings.

It is a further object of this invention to disclose an air cooled turbine wheel wherein the blade bases, or skirts, serve as both impeller vanes and stiffening ribs for the wheel disks.

It is another object of the instant invention to disclose an air cooled turbine wheel construction wherein an insert placed within the blade restricts the flow of cooling air to regions near the inner surface of the blade shell and thereby requires a minimum of cooling air and makes the most effective use of the cooling air thus required.

It is another object of this invention to disclose a turbine wheel construction which can be fabricated out of ferritic steels instead of the high heat resisting alloys which are presently used. The ferritic steels can be used because of the more efficient cooling of the turbine wheel assembly.

It is another object of this invention to disclose a turbine wheel construction which can be fabricated by the use of conventional machine tools and sheet metal techniques and therefore does not require the specialized machinery and expert skill which is presently required.

It is another object of the invention to disclose a turbine wheel construction which readily lends itself toward the conservation of materials in its manufacture both by requiring a lesser weight of material for its construction and by decreasing the amount of materials wasted by needless machining operations.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a view partially in cross section, showing an assembled turbine blade mounted on a turbine wheel;

Fig. 2 is a view showing the island insert which forms the center portion of the turbine blade assembly;

Fig. 3 is a cut-away view showing the island portion of the blade having corrugations surrounding it;

Fig. 4 is a view, partially cut-away, which shows the outer blade shell of the blade assembly mounted on the island insert and on the corrugated portions of the blade assembly;

Fig. 5 is a view similar to Fig. 4 which also discloses one form of sealing shroud mounted relative to the turbine blade shell.

Fig. 2 discloses island insert **10**. This insert can be made either hollow or solid depending upon its size. If it is of hollow construction it is to be noted that it is completely sealed against the entrance of air therein. Affixed to the lower portion of island insert **10**, or formed integral therewith, are arms **11** and **12** to which are suitably attached or affixed tabs **13** and **14**. Tabs 13 and **14** are adapted to be welded, brazed, or otherwise suitably secured to the peripheral flared rim portions **15** and **16** of wheel disks **17** and **18**, respectively, Fig. 1. The wheel disks **17** and **18**, in their most rudimentary form consist of light weight circular plates, having circular apertures (not numbered) centrally located therein. These apertures serve to mount disks **17** and **18** upon hollow shaft **19**. However the disks **17** and **18** shown in Fig. 1 have flared portions **15** and **16**. This construction allows the use of turbine blades having narrow root portions and wider airfoil blade portions. It can be readily seen that in fabricating the turbine wheel a plurality of island inserts **10** are to be positioned and affixed circumferentially about the peripheries of plates **17** and **18**. The following description will refer to the only one turbine blade assembly designated by numeral **20**, Fig. 5, but it is to be understood that in the fabrication of a turbine wheel unit a plurality of these assemblies are to be affixed to the disks **17** and **18**.

An outer blade shell generally designated by numeral **21** is adapted to fit over and partially surround island insert **10**. Blade shell **21** consists of an airfoil portion 22 and a hollow elongated skirt **23**, Fig. 4, effectively formed integrally with airfoil portion **22**. Positioned at the base at both ends of airfoil section **22** are flanges 24 which are adapted to seat on the insert tabs **13** and **14**, Fig. 4. The position of flanges **24** on airfoil section 22 determines the relative radial positioning of the wheel disks **17** and **18** and blade shells **21**. The edges **25** and 25 of hollow elongated skirt **23** of blade shell **21** are adapted to be welded, brazed, or otherwise suitably affixed to wheel disks **17** and **18**. It can thus be seen that this type of blade construction obviates the necessity for interruption of the disk rims. Furthermore since the heat, during turbine operation, is much greater at the rim portions **15** and **16** than at the more centrally located portions of disks **17** and **18**, it can be seen that this construction is advantageous since the centrifugal stress of the turbine blade is distributed radially along the disks **17** and **18** rather than being concentrated at the hotter outer portions of the turbine disks which are weaker than the more centrally located cooler portions. Since the tabs **13** and **14** of the island insert **10** are affixed to the rims of disks **17** and **18**, they carry their own load and do not depend on the connections between the outer blade shell **21** and the disks **17** and **18** for support. The elongated skirt portion **23** of the turbine blade shell **21**, in addition to serving the function of affixing the blade shell **21** to the wheel disks **17** and **18**, also serves the function of providing a series of rigid connections between wheel disks **17** and **18**. These rigid connections act as ribs to unite the wheel disks **17** and **18** and the blade assembly **20** into a strong unitary turbine wheel structure. The radially extending skirt portion **23** serve the further function of acting as impeller vanes for the cooling air as will be more fully described hereafter.

Reference is now made to Figs. 3, 4 and 5. A corrugated intermediate structure **27** is adapted to be positioned between island insert **10** and the blade airfoil portion **22**. This corrugated structure **27** provides bracing between island insert **10** and the blade airfoil portion **22**, and is attached between the latter two members as by welding or brazing, or in any other suitable manner. It will be noted at this point that the structure of the corrugations provides air ducts through which cooling air flows.

Cooling air is supplied to the turbine blade assemblies from a suitable compressor (not shown) via hollow shaft **19** as shown by the arrows in Fig. 1. Shaft **19** has a conical portion **28** having apertures **29** in its periphery through which the cooling air flows. Portion **28** of the shaft **19** is conical in order to provide adequate circumferential space for the flow of air in addition to providing increased rigidity to the structure. A conically shaped sealing plug **30** is affixed to the inside of the conical portion **28** of shaft **19**, Fig. 1. The plug **30** has the function of directing the flow of cooling air to apertures **29** in addition to the functions of sealing the end of shaft **19** and providing greater rigidity for shaft **19**. As the cooling air passes radially outward from apertures **29** it is given tangential velocity by the skirt extension **31** Figs. 4 and 5 which acts as an impeller vane. The skirt extension **31**, it will be noted, is provided only on one side of skirt **23**, namely, on the suction side thereof. This is for the purpose of generating radial flow of the cooling air prior to the entry of the cooling air into the compartment formed by the walls of hollow skirt **23**. It can thus be seen that the cooling air flows through hollow skirt **23**. However since the island insert **10** is sealed against the entry of air, the cooling air is forced around insert **10** as shown by the arrows in Fig. 2 and through the ducts formed by corrugations **27**. It can thus be seen the cooling air is forced between the outside of island insert **10** and the inside of the blade airfoil portion **22**. In this manner a minimum of cooling air is required and that which is required is kept in the most effective location, namely, in contact with the blade shell airfoil section **22**. The cooling air after passing radially through the cooling ducts formed by the corrugations **27** in the blade assembly **21** discharges out of the tip of the blades into the gas stream of the turbine.

A sealing shroud **32**, Figs. 1 and 5, fits around the blade shell airfoil portion **22** and has its edges suitably attached to the flared rims **15** and **16** of wheel disks **17** and **18**, respectively. Lips **33** of shroud **32** fit snugly or may be welded or brazed to blade airfoil section **22**. The sealing shroud **32** serves the function of sealing the turbine wheel assembly so that the cooling air is forced through its aforementioned path in contact with the inner surfaces of blade airfoil section **22**. In addition to this function it also serves to lend greater rigidity to the turbine wheel assembly. The sealing shroud **32** may consist of an individual segment, Fig. 5, for each blade assembly or may be made of segments which are large enough to accommodate a plurality of blade assemblies. A portion of the cooling air may circulate by convection within the space defined by the wheel disks **17** and **18**, the skirt portions **23**, and the sealing shroud **32**. Alternately, bleed apertures **34** may be provided in the shroud **32** for allowing partial bleed of the cooling air. The choice of either of the foregoing constructions depends on the cooling requirements needed for the particular application under consideration.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Having thus described my invention I claim:

1. A turbine wheel assembly comprising a hollow shaft, a pair of spaced disks mounted on said shaft, communicating apertures in said shaft leading from said hollow portion of said shaft to the space between said spaced disks, a plurality of turbine blade assemblies radially mounted in circumferentially spaced relationship between said disks, each of said assemblies consisting of an island insert, said island insert being affixed to the peripheral portions of said disks, a hollow blade shell having an airfoil portion and a skirt portion, said airfoil portion surrounding said island insert along the longitudinal axis thereof, said skirt portion extending radially between said spaced disks and being affixed to each of said spaced disks, a corrugated intermediate member positioned between said island insert and said blade airfoil portion, and a sealing shroud extending between said disk peripheries and around said blade assemblies substantially at the junction of said airfoil and skirt portions of said blade shell.

2. A turbine wheel assembly comprising a hollow shaft, a plurality of spaced disks mounted on said shaft, said disks being free of undercuts and transverse cutouts adjacent the peripheries thereof, communicating apertures in said shaft positioned between said spaced disks, a plurality of turbine blade assemblies extending in a substantially radial direction with respect to said disks and being circumferentially spaced with respect to said disks, said turbine blade assemblies consisting of a hollow turbine blade shell having an airfoil portion and a skirt portion, said airfoil portion extending beyond the peripheries of said disks, said skirt portion being elongated and extending between said disks and having one side thereof affixed to each of said disks over a region extending radially inwardly of the disk rim, and a sealing shroud extending between said disk peripheries and around said blade shell substantially at the junction of said airfoil and skirt portions of said blade shell.

3. A light weight turbine wheel assembly adapted to be air cooled comprising a hollow shaft for conducting cooling air, a plurality of spaced disks mounted on said shaft, communicating apertures in said shaft positioned between said disks to conduct cooling air from said hollow shaft to the space between said disks, a plurality of turbine blade assemblies circumferentially positioned with respect to said disks and extending substantially radially with respect to said disks, each of said assemblies comprising an island insert affixed to the peripheral portions of said disks, a hollow blade shell having an airfoil portion and an elongated skirt portion, said airfoil portion extending around said island insert in a longitudinal direction, said elongated skirt portion extending between said disks and being affixed thereto, an intermediate member positioned between said island insert and said blade airfoil portion for supporting the latter two members relative to each other, and a sealing shroud extending between said disks and around said blade shells for sealing the turbine wheel assembly whereby the cooling air is caused to flow from the space between the disks through the skirt portion of the blade shells and then between the island insert and the interior surface of the airfoil portion for the purpose of cooling the airfoil portion of said blade assembly.

4. A light weight turbine wheel assembly adapted to be air cooled comprising a pair of spaced disks having uninterrupted peripheries, a flared rim portion on each

of said disks, said flared rim portion on each of said disks extending away from the other of said disks, a plurality of turbine blade assemblies mounted in circumferentially spaced relationship about said disks and extending substantially radially with respect to said disks, each of said blade assemblies comprising an island insert affixed to said disk rims, a hollow turbine blade having an airfoil portion and a skirt portion which is narrower than said airfoil portion, said airfoil portion surrounding said island insert in a longitudinal direction and extending beyond said disk rims, said skirt portion extending between said disks and being affixed to each of said disks, ribbed members affixed between said island insert and said blade airfoil portions, and a sealing shroud affixed to each of said rims.

5. A turbine wheel assembly adapted to be air cooled comprising a pair of spaced circular disks, a plurality of turbine blade assemblies mounted in circumferentially spaced relationship relative to said disks, said assemblies comprising an island insert affixed to the peripheral portions of said disks, a turbine blade shell having an airfoil portion and an elongated skirt portion, said airfoil portion surrounding said island insert in a longitudinal direction, said skirt portion extending between said disks and being affixed to each of said disks, an intermediate bracing structure affixed between said island insert and said turbine blade airfoil portion, and a sealing shroud affixed between the peripheral portions of said disks, said sealing shroud having bleed apertures therein.

6. A turbine wheel assembly as set forth in claim 5 wherein a skirt extension is affixed to one side of said elongated blade skirt.

7. A light weight turbine wheel assembly adapted to be air cooled comprising a plurality of spaced disks having uninterrupted rim portions, a plurality of turbine blade assemblies mounted in circumferentially spaced relationship relative to said disks, each of said assemblies comprising an island insert affixed to said rim portions, a turbine blade shell having an airfoil portion and a skirt portion which is narrower than said airfoil portion, said airfoil portion surrounding said island insert in a longitudinal direction, an intermediate structure affixed between said island insert and said airfoil portion, said skirt portion extending between said disks and being affixed to each of said disks, a blade skirt extension attached to one side of said elongated skirt portion, and a sealing shroud affixed between the peripheral portions of said disks.

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