Sept. 24, 1957 C. E. HOCKERT 2,807,436

TURBINE WHEEL AND BUCKET ASSEMBLY

Filed March 25, 1952 2 Sheets-Sheet 1

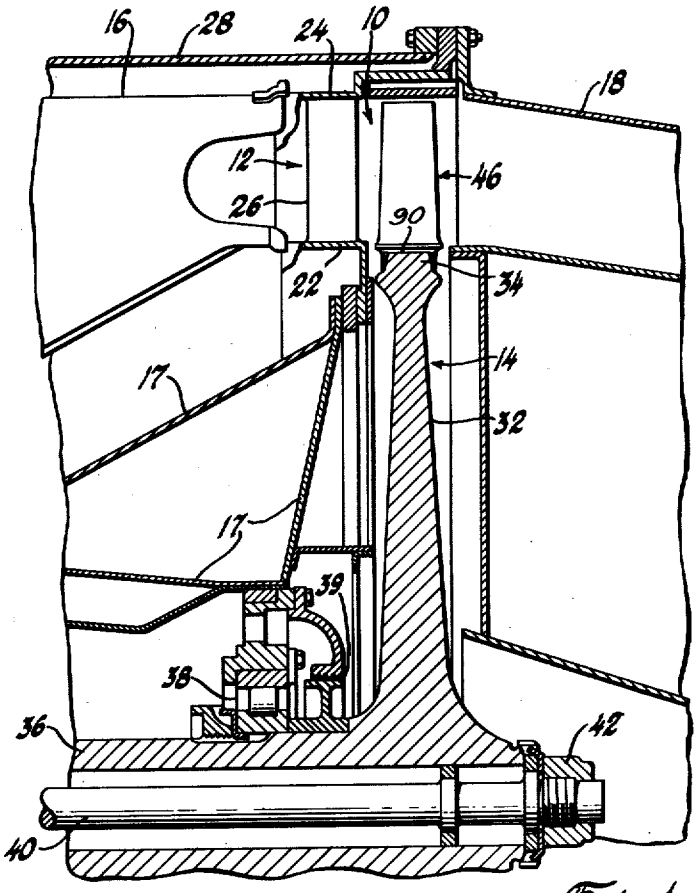


Fig. 1

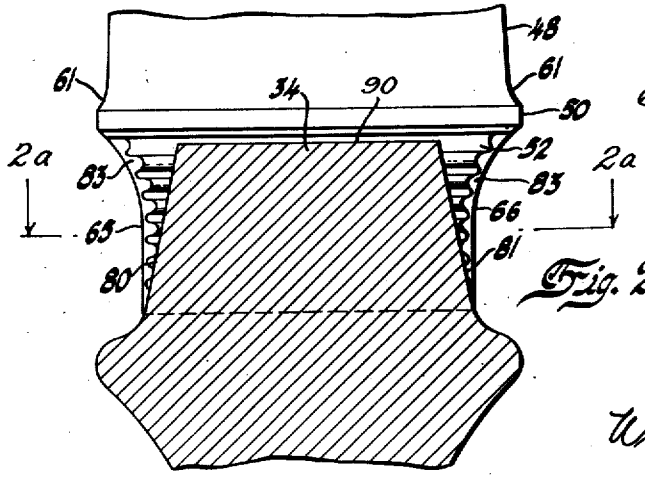


Fig. 2

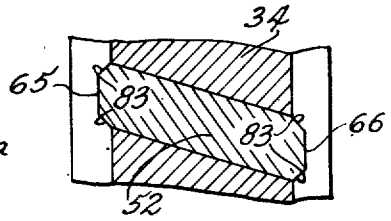


Fig. 2a

INVENTOR.
Chester E. Hockett
BY
Williston, Helwig & Baillio
ATTORNEYS

Sept. 24, 1957 C. E. HOCKERT 2,807,436

TURBINE WHEEL AND BUCKET ASSEMBLY

Filed March 25, 1952 2 Sheets-Sheet 2

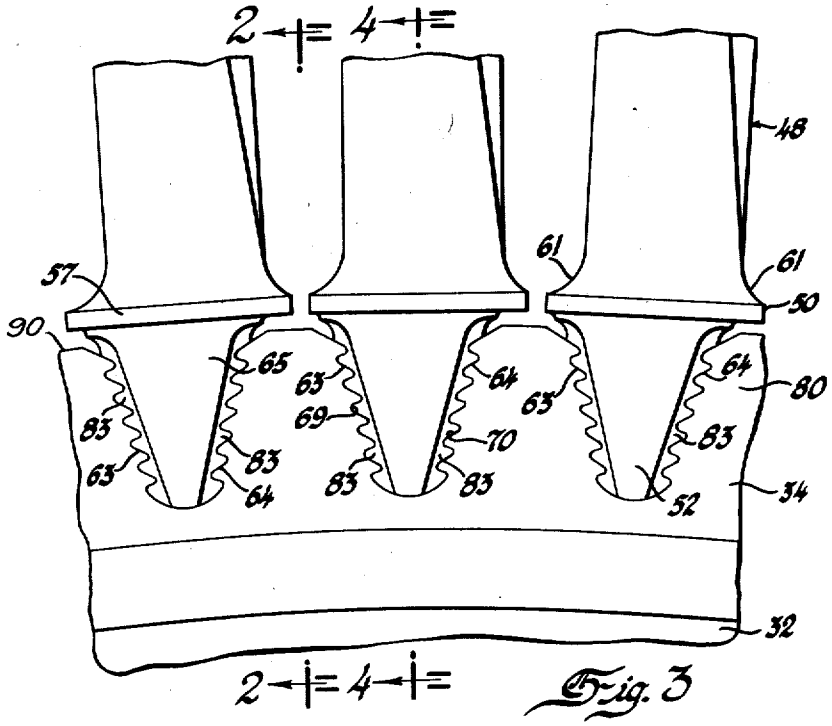


Fig. 3

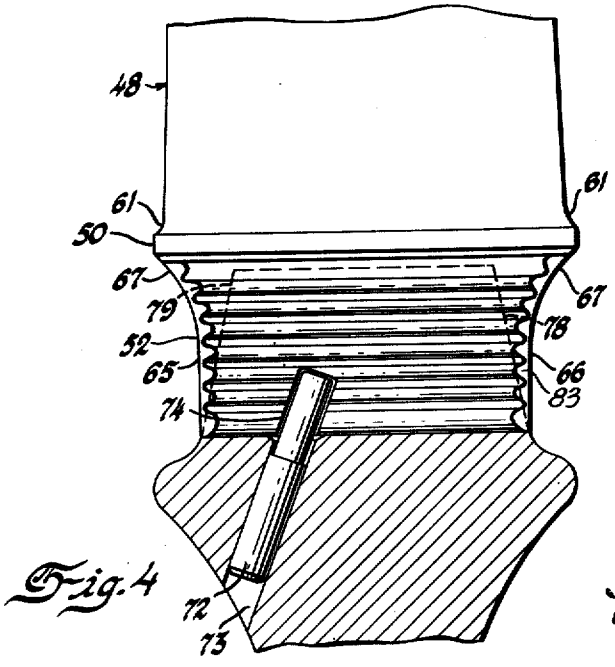


Fig. 4

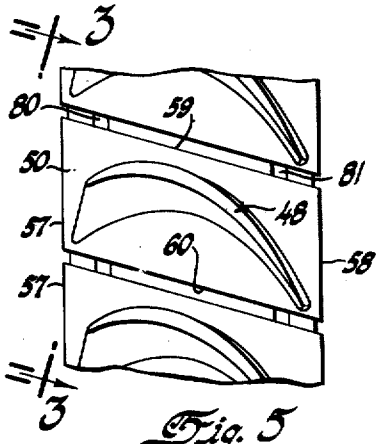


Fig. 5

INVENTOR.
Chester E. Hockert
BY
Willis, Kleinig & Baillio
ATTORNEYS

United States Patent Office 2,807,436 Patented Sept. 24, 1957

2,807,436

TURBINE WHEEL AND BUCKET ASSEMBLY

Chester E. Hockert, Indianapolis, Ind., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Application March 25, 1952, Serial No. 278,459

6 Claims. (Cl. 253—77)

My invention relates to elastic fluid turbines and the like and, more particularly, to an improved construction for a turbine wheel and bucket assembly for mitigating stresses and reducing failures in turbine buckets.

Turbine buckets with "fir-tree" or serrated dovetail roots are commonly employed in the rotors of gas turbine engines and comprise, in general, a blade portion, a platform portion, and a wedge-shaped root portion formed with smooth ends and serrated faces. The buckets are slidably mounted in wedge-shaped slots having serrated sidewalls extending generally axially across the turbine wheel rim and are loosely fitted therein to allow for vibration damping. The platform portion of the buckets employed in some turbine installations may overhang the ends of the root portions thereof, whereby the bucket is of notched section and consequently stressed due to abrupt changes in the cross section thereof.

I have noticed that turbine buckets of the overhanging platform variety are subject to frequent fatigue-type fractures that originate in the dovetail root. These failures are believed to be attributable to loads exerted on the ends of the bucket root by axial components of torsional bending moments caused by fluttering of the bucket in the wheel rim and to centrifugal operating stresses that tend to pull the bucket out of its slot. These factors subject the bucket to loads that exceed the fatigue limit of the notched section with consequent fracturing thereof.

While the tensile strength and fatigue limit of the bucket could be increased somewhat by increasing the length of the bucket root so as to eliminate platform overhang and the resulting notch effect, this would not remove the loads from the ends of the bucket root and would require increasing the thickness of the turbine wheel rim, which is generally undesirable, particularly in aircraft installations where considerations of weight are of importance. Although elimination of bucket flutter to remove end loading of the bucket root would appear to be an ideal solution, this is difficult to accomplish effectively and in addition would tend to offset the desirable effects of vibration damping resulting from loosely fitted buckets.

Accordingly, it is the general object of my invention to provide an improved construction for a turbine rotor wheel and bucket assembly, wherein fatigue-type stresses occurring in the dovetail bucket root are mitigated. Another object is to provide a turbine wheel and bucket assembly that is of minimum weight and wherein fatigue-type stresses occurring in the bucket root are mitigated. Another object is to provide a turbine wheel and bucket assembly wherein fatigue-type stresses occurring in the bucket root are mitigated without increasing the dimensions of the wheel rim or reducing bucket flutter.

In accordance with my invention, I provide an improved wheel and bucket assembly wherein fatigue-type stresses occurring in the bucket root are eliminated without increasing the dimensions of the wheel. In fact, material from the wheel and bucket is removed so as not only to lessen the weight of the wheel assembly but also

to substantially eliminate bucket root stresses. For accomplishment of these ends, I provide a turbine wheel which mounts a number of turbine buckets of the serrated dovetail root variety wherein the wheel rim is of tapered section and the edges between the ends and serrated faces of each of the bucket roots are chamfered, for reasons that will be mentioned.

The preferred manner in which these and other objects of my invention are realized, together with the attending features and advantages thereof, will appear more fully from the following detailed description and drawings, wherein; Fig. 1 is a longitudinal sectional view of a portion of a gas turbine engine embodying a turbine wheel and bucket assembly in accordance with the invention; Fig. 2 is an enlarged sectional view of a portion of the wheel and bucket assembly of Fig. 1 taken on the line 2—2 of Fig. 3; Figure 2*a* is a sectional view taken on the line 2*a*—2*a* of Figure 2; Fig. 3 is an enlarged fragmentary face view of the wheel and bucket assembly of Fig. 1 taken on the line 3—3 of Fig. 5; Fig. 4 is a fragmentary view partly in section taken on the line 4—4 of Fig. 3; and Fig. 5 is a developed plan view of a portion of the turbine wheel in accordance with the invention.

Referring to the drawings, Fig. 1 illustrates the turbine portion of a gas turbine engine of known type embodying a turbine wheel and bucket assembly in accordance with the invention. The turbine **10** comprises a stator **12** and a rotor **14** which are shown disposed between the discharge end of the combustion apparatus **16** and the turbine exhaust casing **18** of the engine. The turbine stator **12** is supported from the interior of the engine in known manner by an annular frame **17** and comprises a flanged inner ring **22** and a stepped or offset outer ring **24** between which is mounted an annular row of radially spaced stator vanes **26**. The outer ring **24** is supported from the inner ring **22** by the vanes **26** and supports the turbine exhaust duct **18** and a flanged casing **28**, which surrounds the discharge end of the combustion apparatus **16** and turbine **10**, as shown.

The turbine rotor **14** comprises a wheel having a disk portion **32** and a rim portion **34** with an integrally formed hollow shaft **36** that extends axially from the hub or central portion of the wheel. The portion of the shaft adjacent the forward face of the wheel is supported by a bearing **38** mounted in the frame **17**. A seal **39** prevents escape of lubricant from the bearing. A tie bolt **40** secured by a nut **42** passes through the interior of the hollow shaft **36**.

The turbine wheel mounts a row of turbine buckets **46** spaced about the periphery of the rim portion **34**. Each bucket is an integrally formed element comprising a blade portion **48**, a platform portion **50**, and a wedge-shaped root portion **52** as shown in Figs. 2, 3 and 4. As best shown in the plan view of Fig. 5, the blade portion **48** is of an airfoil shape with one convex and one concave face and is twisted throughout its length. The platform portion **50** is shown as a parallelogram with parallel ends **57**, **58** and faces **59**, **60** that extend beyond the corresponding ends and faces of the blade portion, the base of the latter being smoothly united to the upper surface of the platform by fillets **61** (Figs. 2, 3 and 4). The root **52** is of the fir-tree or serrated dovetail variety with serrated side faces **63**, **64** (Fig. 3), which converge downwardly from the lower surface of the platform **50**, and spaced flat ends **65**, **66** which are smoothly united with the bucket platform portion by fillets **67** under the ends of the latter.

The buckets are slidably mounted in circumferentially spaced radially extending wedge-shaped slots having side walls **69**, **70** (Fig. 3) which extend somewhat obliquely across the wheel rim, the depth of the slots being such

that the periphery 90 of the wheel extends above the top dovetail root serration just below the bucket platform. The buckets are loosely fitted in their slots to permit slight lateral movement thereof for vibration damping. The sidewalls of the slots are serrated to mate with the serrations on the sides or faces 63, 64 of the bucket root so as to prevent radial movement of the buckets. Each of the buckets is retained in the wheel by a retaining pin 72 (Fig. 4) which is driven into a hole 73 in the wheel into a slot 74 in the bottom of the bucket root, as shown.

The faces of the wheel rim have previously been flush with the ends 65, 66 of the bucket roots so that the ends of the bucket roots are received or confined in the wheel. The length of the bucket platform 50 is equal to or slightly greater than the chord length of the blade 48 which, in many cases, is of greater length than the slots in the turbine wheel rim so that the blade and platform portions overhang the bucket root, as exemplified herein. The bucket, therefore, is of notched section and of reduced tensile strength by reason of the stress concentrations appearing in the notched region thereof. The sharp corners between the ends 65, 66 and faces 63, 64 of the bucket root constitute stress risers where fractures are first likely to develop if the loads exerted on the bucket exceed the fatigue limit thereof.

The loads exerted on the buckets are due chiefly to centrifugal operating stresses which tend to pull the buckets out of their slots in the wheel rim and to components of torsional bending moments caused by fluttering of the buckets as they wipe past successive high velocity gas streams directed through the turbine nozzle. The centrifugal operating stresses are of maximum intensity along the top dovetail serrations on the faces of the bucket roots. The torsional vibration forces developed by fluttering of the buckets tend to twist the buckets and have an axial component exerted on the ends of the bucket root. It is believed that the fatigue-type failures exhibited by such buckets, in the form of a fracture that originates in the root of the top dovetail serration along the acute corner at the backface of the bucket root and progress unevenly upward through the platform portion and terminate in the leading edge of the blade, are attributable to the above factors.

I have been able to reduce the number of such bucket failures by removing the loads exerted in the ends of the bucket roots and removing the stress risers at the corners thereof. In accordance with my invention, I eliminate the stresses from the ends of the bucket root by providing a wheel rim of tapered section to expose or extend the ends 65, 66 of the bucket roots beyond the tapered faces 80, 81 of the wheel rim. I eliminate the stress risers from the bucket roots by provision of chamfers along the serrated corners or edges between the ends 66 and 67 and faces 63, 64 of the bucket roots. More specifically, the axial length of the wheel is made less than the axial length of the bucket root where the latter engages the wheel rim by tapering the wheel rim inwardly toward the periphery thereof through a radial distance preferably at least equal to the depth of the bucket slots provided therein. The chamfers are shown in Fig. 3 as flat bevel surfaces 83 between the ends and faces of the bucket roots at about 45° to the planes of the faces of the roots. The width of the chamfers or bevel surfaces 83 is preferably sufficiently great that the bevel surface extends beyond the bottoms of the dovetail serrations in the faces of the bucket roots.

By providing a wheel rim of tapered section, the torsional and centrifugal loads exerted on the ends of the bucket root are removed from the end portions of the latter extending beyond the tapered faces of the wheel rim and are concentrated toward the central portion thereof, thereby increasing the bucket load carrying ability and reducing the peak level of stresses in the vicinity of the notched section of the bucket. Chamfering the edges of the bucket roots eliminates the stress risers at the edges so as to prevent fractures from developing therein.

There is thus provided a turbine wheel and bucket assembly which has been found efficacious to reduce concentrations in bucket loads and failures in bucket roots where fractures have been most common, thereby improving the strength and reliability of the turbine wheel assembly. Although the invention has been described with reference to one specific form of bucket root, the underlying principles thereof can be applied to other forms of blades and buckets having a root portion adapted for mounting in a rotor wheel slot.

I claim:

1. In combination, a turbine bucket having a root portion having a width bounded by oppositely facing serrated surfaces and an axial length bounded by oppositely facing smooth end surfaces, flat bevel surfaces connecting said serrated and end surfaces, a turbine wheel having a rim portion on its periphery, said rim portion having an axially extending slot receiving said bucket root therein, said slots having axially extending side walls cooperating with said bucket root serrated surfaces to prevent radial movement thereof, said wheel rim being tapered radially inwardly toward the periphery thereof and having an axial width at its periphery less than the axial length of said bucket root portion between said smooth end surfaces at the periphery of the wheel.

2. In combination, a turbine bucket having a root portion having a width bounded by oppositely facing serrated surfaces and an axial length bounded by oppositely facing smooth end surfaces, flat bevel surfaces connecting said serrated and end surfaces, a turbine wheel having a rim portion on its periphery, said rim portion having an axially extending slot receiving said bucket root therein, said slots having axially extending side walls cooperating with said bucket root serrated surfaces to prevent radial movement thereof, said wheel rim being tapered radially inwardly toward the periphery thereof through a radial distance at least equal to the radial depth of said slot and having an axial width at its periphery less than the length of said bucket root portion between said smooth end surfaces of the periphery of the wheel.

3. In combination, a turbine bucket having a root portion having a width bounded by oppositely facing serrated surfaces and an axial length bounded by oppositely facing smooth end surfaces, flat bevel surfaces connecting said serrated and end surfaces, a turbine wheel having a rim portion on its periphery, said rim portion having an axially extending slot receiving said bucket root therein, said slots having axially extending side walls cooperating with said bucket root serrated surfaces to prevent radial movement thereof, said wheel rim being tapered radially inwardly toward the periphery thereof and having an axial width at its periphery less than the axial length of said bucket root portion between said smooth end surfaces at the periphery of the wheel, the width of said bevel surfaces between their connections to the serrated and end surfaces being greater than the depth of the serrations in the serrated surfaces.

4. In combination, a rotor wheel having a rim portion with a plurality of circumferentially spaced peripheral slots extending generally axially across the rim, said slots having axially extending serrated side walls, a plurality of blades each having a root portion extending into one of said slots, said root portion being bounded by oppositely facing axially extending serrated surfaces connected by chamfered edges to oppositely facing smooth end surfaces, said serrated surfaces cooperating with said serrated side walls for holding said blades against rotary movement relative to said rotor wheel, said rim being of continuous radially tapered section from the periphery of said wheel to the bottom of said slots and being of lesser axial width than the axial length of the root portion between said smooth end surfaces at the periphery of the wheel.

5. In combination, a rotor wheel having a rim portion

with a pair of axially spaced faces, and a plurality of spaced peripheral slots in the rim portion extending between the faces of the rim, and a plurality of blades each having a root portion in one of said slots with spaced end surfaces generally parallel to said rim faces and generally axially extend lateral surfaces joining said end surfaces, interengaging means on said root portions and said rim portion for preventing radial separation between the blades and the wheel, said rim being of continuous radially tapered section from the periphery of the wheel to the bottom of the said slots, and being of lesser axial width than the axial length of the root portion of said blades between said end surfaces at the periphery of the wheel, and the corners between said lateral and end surfaces of the root portion of each of the blades being chamfered.

6. In combination, a rotor wheel having a rim portion with a pair of axially spaced faces, said rim portion having at least one peripheral slot therein extending generally axially between the faces of the rim, and a blade having a root portion in said slot with spaced end surfaces generally parallel to said rim faces and generally axially extending lateral surfaces joining the end surfaces, means

for preventing radial movement of said root portion relative to said slot, said rim being of continuous radially tapered section from the periphery of the wheel to the bottom of the slot therein and being of lessser axial extent than the axial length of said blade root portion at the periphery of the wheel, the corners between the said lateral surfaces and end surfaces of the root portion of said blade being chamfered.

References Cited in the file of this patent

UNITED STATES PATENTS

874,398	DeFerranti	Dec. 24, 1907
1,095,587	McIntosh	May 5, 1914
1,313,152	Yarrow	Aug. 12, 1919
1,890,581	Kohler	Dec. 13, 1932
2,605,996	Sturgess	Aug. 5, 1952

FOREIGN PATENTS

170,177	Germany	May 1, 1906
241,993	Switzerland	Sept. 2, 1946
613,667	Great Britain	Dec. 1, 1948