

[54] **METHOD AND MEANS FOR RETAINING CERAMIC TURBINE BLADES**

[75] Inventors: **Axel Rossmann; Wilhelm Hoffmüller**, both of Munich, Germany

[73] Assignee: **Motoren-Und Turbinen-Union**, Munich, Germany

[22] Filed: **Feb. 22, 1972**

[21] Appl. No.: **227,809**

[30] **Foreign Application Priority Data**

Feb. 20, 1971 Germany..... P 21 08 176.5

[52] U.S. Cl..... **416/215, 416/219, 416/241**

[51] Int. Cl..... **F01d 5/30**

[58] Field of Search..... 416/241, 219-221, 416/215

[56] **References Cited**

UNITED STATES PATENTS

2,317,338	4/1943	Rydmark	416/221
2,874,932	2/1959	Sörensen.....	416/220
3,317,988	5/1967	Endres	416/220 UX

FOREIGN PATENTS OR APPLICATIONS

892,785	1/1944	France	416/241
1,163,439	4/1958	France	416/215

664,986	1/1952	Great Britain	416/241
753,229	7/1956	Great Britain	416/220
914,548	1/1963	Great Britain	416/241

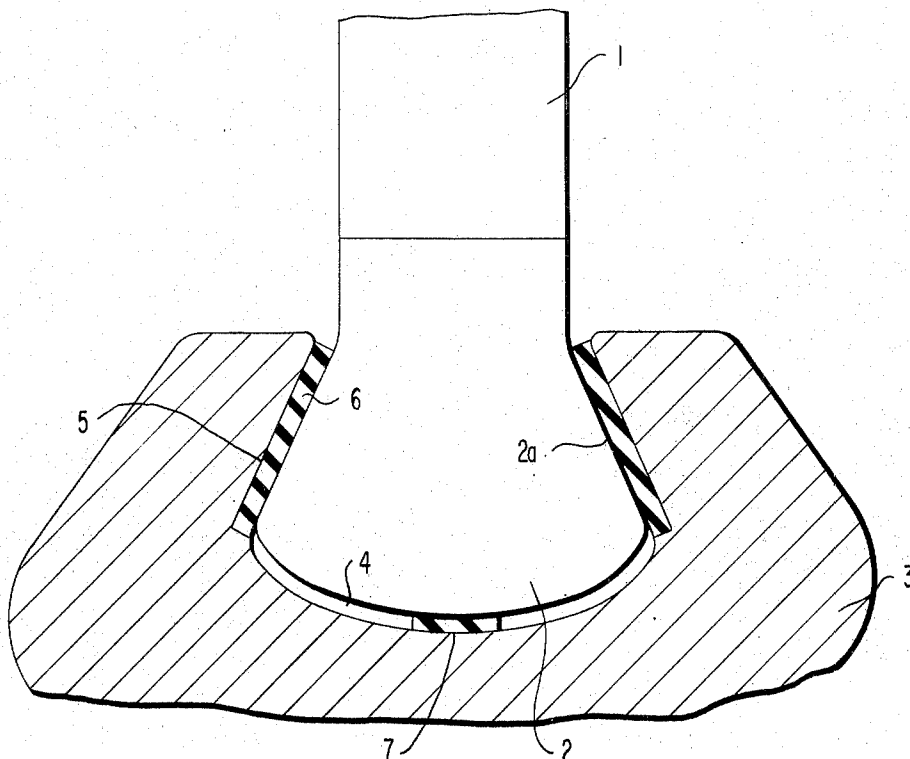
Primary Examiner—Everette A. Powell, Jr.

Attorney—Paul M. Craig, Jr. et al.

[57] **ABSTRACT**

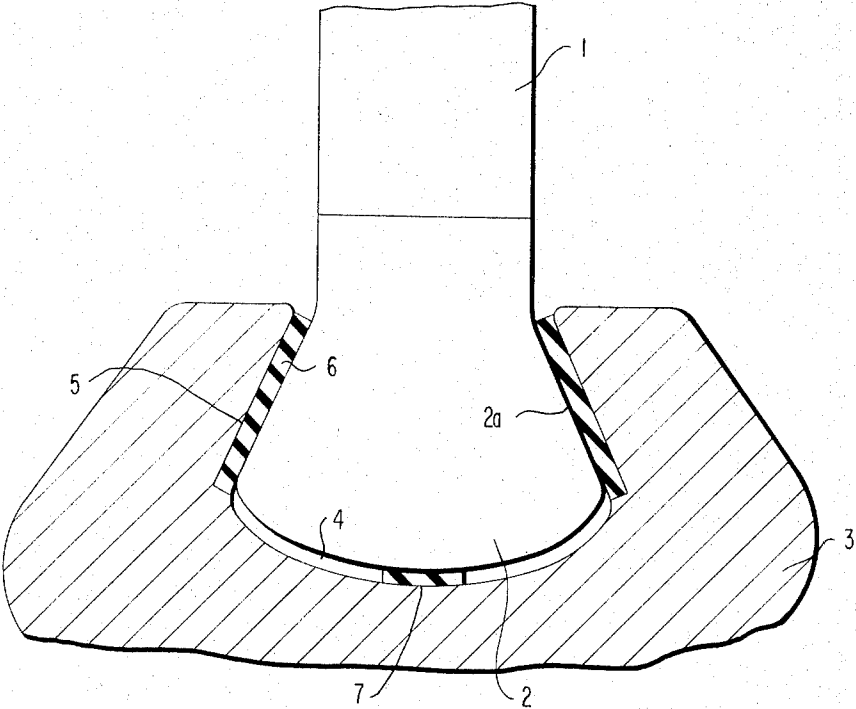
A method and means for retaining ceramic turbine blades in steel rotors using metallic felt shims interposed between the edges of the blade root and side walls of a slot formed in the rotor. The metallic felt shims are formed of very thin metallic fibers sintered together to form a thin sheet of felt material. This sintered felt sheet is then compressed beyond its first plastic limit, at which point it again becomes elastic, exhibiting favorable elastic properties for absorbing the relatively large rotative and centrifugal forces between the rotor and blade during use. Since the force between blade and rotor transfer is almost exclusively through elastic deformation of the shim means, the friction coefficients between the shim and rotor or blade structure need not be precisely controlled. The shim is fixed to the rotor structure by brazing or the like. The predeformed metal felt material also acts as a heat insulator to prevent or inhibit the transfer of high blade temperatures and heat to the rotor.

20 Claims, 2 Drawing Figures



PATENTED JAN 8 1974

3,784,320



METHOD AND MEANS FOR RETAINING CERAMIC TURBINE BLADES

BACKGROUND OF THE INVENTION

This invention relates to means for anchoring ceramic turbine blades in a circumferentially walled slot in a steel rotor or blade seating ring using shims of a heat resistant metallic material arranged between the blades and the rotor.

German Pat. No. 943,863 discloses a turbine rotor of steel construction having ceramic blading and metallic layers intervening between the blades and the steel rotor. The intervening layer of this patent consists of shims of a non-scaling, heat resistant metallic material loosely arranged between the bearing surfaces of the blade root and the supporting surfaces of a suitably conformed seat in the rotor. Since, in operation the blade is subject to an outward pull under large centrifugal forces, the shims of this patent are intended to improve the friction ratios at the bearing surfaces. A difficulty with this arrangement is that the friction ratios are very difficult to control adequately especially at elevated temperatures. A further difficulty with this arrangement is that in the process of deformation the loosely arranged metallic shim will inevitably set, so that localized compression may be the cause of stress peaks in the shim and steel rotor with the resulting failure of the materials.

DESCRIPTION OF THE INVENTION

The present invention contemplates the provision of means for retaining turbine blades, especially ceramic turbine blades in rotors, especially steel rotors, such that uniform transfer of the retaining force is ensured despite the dimensional tolerances imposed by manufacturing practice and such that the largely uncertain friction ratios at the bearing surfaces can be ignored. The present invention also contemplates a method for constructing the means to carry out these functions.

The present invention further contemplates providing means for safely avoiding local load concentrations and the ensuing stress peaks while promoting the thermal fatigue strength. The present invention also contemplates the provisions of a seating arrangement for ceramic turbine blades which is economical in manufacture, easily maintainable in use, and reliable over long periods of time.

The present invention further contemplates the provision of an arrangement for retaining turbine blades, especially ceramic turbine blades, in a circumferentially extending slot of a rotatable rotor, especially a steel rotor, including walls on the slot including inclined portions with a surface component facing inwardly toward the axis of rotation of the rotor, surfaces on the blade arranged in the slot approximately parallel to the inclined portions at a small spacing from the inclined portions, and shim means positioned between the inclined portions and the surfaces on the blade wherein the shim means are constructed of sintered metal felt which has been predeformed beyond a first plastic limit so that it exhibits highly elastic properties for elastically absorbing the large centrifugal forces between the rotor and blade during use whereby the relative movement of the blade and rotor is primarily a function of the elasticity of the shim and wherein the shim means also forms a thermal insulation between the rotor and the blade.

The present invention further contemplates the provision of a method for retaining turbine blades, especially ceramic turbine blades, in a circumferentially extending slot of a rotatable rotor, especially a steel rotor, including forming the slot and the surface of the blade so as to have respective parallel surfaces facing one another with the slot surface having a surface component facing relatively inwardly toward the axis of rotation of the rotor, constructing shim means of sintered metal felt, predeforming the shim means beyond a first plastic limit so that the shim means exhibits elastic properties and high strength, and placing the predeformed shim means between the respective parallel surfaces of the slot and blade whereby the shim means effectively elastically absorbs the transfer of centrifugal forces between said rotor and blade during use.

The present invention contemplates providing these above-mentioned benefits by arranging a shim between the internal walls of the steel rotor slot and the suitably conformed flanks of the blade root which shim is constructed of a heat resistant, sintered, highly flexible and elastic metallic felt previously deformed, after having been sintered, beyond its first plastic limit. The invention further contemplates attaching the shim to one of the walls of the slot or the blade.

The basic material contemplated for use in the present invention for forming the metallic felt has been finding use particularly in filter work and seals and consists of a uniform metallic felt composed of, for example, 6 to 15 μm diameter fibers sintered by the application of high heat, pressure and reduced atmosphere to form a metallic bond between the fiber particles along their contact surfaces. The density, or the pore volume of the sintered basic material, which exhibits elastic properties until the proportional limit is reached, can be adjusted primarily by dosing the pressure during sintering. The pore volume, as well as the strength of the metallic felt shim is then optimized according to the present invention by deformation after sintering. This deformation may be achieved, for example, in a suitable press or as a result of centrifugal force during a trial run on a blade and rotor assembly.

While the analysis, 1.5 percent Co, 22 percent Cr, 9 percent Mo, 0.6 percent W, 18 percent Fe, 0.10 percent C, 1.0 percent Si, 1.0 percent Mn, balance Ni, is representative of a suitable felt material, a material on Co base or of other alloy constituents would equally be practicable for use in the present invention.

It is contemplated by the present invention to deform the sintered basic material beyond its first plastic limit (this first plastic limit for the sintered material, it being understood that a plastic limit for the basic unsintered material is surpassed during sintering due to the high temperature and the pressure conditions experienced during the sintering process). The thus deformed metallic felt shim is distinguished with a high degree of elasticity and very high strength. The range of elasticity of the deformed felt is particularly suited for the range of forces experienced in turbine rotor and blade assemblies of the type referred to herein, such that during operation of the rotor, the elastic limit is not exceeded thereby preventing stress peaks in the shim. For example, the sintered basic material, once it has exceeded a first plastic limit (order of magnitude of 10 to 10³ kp/cm²) can be compressed into a very elastic body exhibiting a very respectable crushing limit (order of magnitude of 10³ kp/cm²). Note that 1 kp equals 1,000

grams. Also, the term "crushing limit" refers to a second plastic limit of the sintered metallic shim material. Therefore, the present invention contemplates use of the felt material over the elastic range between a first plastic limit and a crushing or second upper plastic limit. Another special merit of the metallic felt shim according to the present invention is that despite the presence of a host of pore cells, its structure is substantially uniform such that it possesses consistent and uniform mechanical and thermic properties to ensure uniform transfer of the retaining force while avoiding the build-up of stress peaks. An additional advantage of the shim of the present invention is found in its notable capability to dampen blade vibrations.

The thinner the shim material used, the larger will be the modulus of resilience ($c = p/f$ (kp/cm)) or specific restoring force. P = spring bias or constant and f = spring stroke. A shim constructed of the predeformed felt material contemplated by the present invention (see specific thickness on example described), as compared with an equally large, equally thick shim of solid steel, with the same spring stroke (f), the thus produced forces (p) in the first mentioned case are substantially smaller, for example, approximately 10 times smaller than is the latter case. Therefore, the arrangement contemplated by the present invention avoids peak stresses in areas of locally concentrated loads.

Another asset of the shim in accordance with this invention is that it offers a wide range of elastic deformability without setting during rotation of the blades and that it therefore practically eliminates the problem of controlling the friction ratios at the bearing surfaces. In this, the high normal forces acting on the shims cause their elastic deformation such that the radial movements of the blade are proportional to the deformation of the shims. As a result, the movement of the blade is primarily not a function of the friction but is exactly governed by the elasticity of the shim.

The metal felt shim contemplated by the present invention is further characterized not only by its remarkable heat resistance but also by its low thermal conductivity. This is of particular advantage in that but a small portion of the heat is transferred from the blade root, where the temperature level may in some instances be depressed using specially ducted cooling air, to the turbine rotor. Consequently, the requirements imposed on the rotor material in the matter of heat resistance are therefore mitigated permitting the use of less costly materials for the rotor. Owing to the thermal insulation provided by the layer of metallic felt the thermal fatigue strength of the blades is equally improved in that the heat is stored in the highly heat-resistant ceramic blades and prevented from immediately spreading into the large bulk of the rotor body.

The accompanying drawing is a sectional view illustrating an embodiment of the blade seating means assembled in accordance with this invention. A dovetailed root 2 of a silicon nitride (Si_3N_4) turbine blade 1 is seated in a circumferential slot 4 in a steel rotor 3. Arranged between the flanks 2a of the blade root and the parallelly extending walls 5 of the circumferential slot 4 is a shim 6 of a heat resistant, sintered and predeformed metallic felt construction secured in place by brazing or other suitable means. To support the blade at rest such that the flanks 2a are held against the shims 6 a strip 7 of metallic felt having the above-described

properties is inserted in the bottom of the circumferential slot 4.

The shims 6 and strip 7 of the example illustrated may be constructed of material consisting of 1.5 percent Co, 22 percent Cr, 0 percent Mo, 0.6 percent W, 18 percent Fe, 0.10 percent C, 1.0 percent Si, 1.0 percent Mn, balance Ni. Also materials on Co base or other alloy constituents would be practical for use in conjunction with the present invention. The thickness of the sintered material before deformation could be, for example, approximately 1.25 mm, which thickness would be compressed to approximately 1.00 mm during the predeformation step. The pore volume of the shim material after predeformation, could be approximately 20 percent of the total volume of the shim. The pore volume is naturally greater prior to the predeformation step. The diameter of the blade carrier ring in the zone of the metal felt shim could be approximately 80 mm. The above dimensions are given by way of example only for a turbine rotor or blade construction usable on an automobile gas turbine engine.

Other possible embodiments are also contemplated by this invention, such as one in which a blade seating ring is split axially or radially for bolting together, after the blade has been inserted, the two wall portions carrying the metallic felt.

While we have described only several embodiments and illustrated only one embodiment in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to those skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

We claim:

1. An arrangement for retaining turbine blades, especially ceramic turbine blades, in a circumferentially extending slot of a rotatable rotor, especially a steel rotor, comprising: wall means forming said slot including inclined portions with a surface component facing inwardly toward the axis of rotation of the rotor, surface means on said blade arranged in said slot approximately parallel to said inclined portions at a small spacing from said inclined portions, and metallic shim means positioned between the inclined portions and the surface means, said shim means being constructed of a sintered metal felt material which has been predeformed beyond a first plastic limit so that it exhibits highly elastic properties for elastically absorbing the large centrifugal forces between the rotor and blade during use whereby the relative movement of the blade and rotor is primarily a function of the elasticity of the shim, said shim means also forming a thermal insulation between the rotor and the blade.

2. An arrangement according to claim 1, wherein said shim means is fixedly attached to one of said inclined portions and said surface means.

3. An arrangement according to claim 1, wherein said shim means is fixedly attached to said inclined portions by brazing.

4. An arrangement according to claim 2, wherein said shim means is approximately one millimeter thick after predeformation and without any compressive loads.

5. An arrangement according to claim 2, wherein said shim means is composed of metal fibers approxi-

5

mately 6 to 15 μm in diameter which are sintered by the application of high heat, pressure and reduced atmosphere to form a metal felt structure which is then predeformed by compression.

6. An arrangement according to claim 5, wherein said metal fibers consist of 1.5 percent Co, 22 percent Cr, 9 percent Mo, 0.6 percent W, 18 percent Fe, 0.10 percent C, 1.0 percent Si, 1.0 percent Mn, balance Ni.

7. An arrangement according to claim 2, wherein further shim means of similar material are provided between the radially innermost end of the blade and the bottom of the slot.

8. An arrangement according to claim 1, wherein said slot and the radially inner end of said blade are of corresponding triangular cross-section shapes.

9. A method for retaining turbine blades, especially ceramic turbine blades, in a circumferentially extending slot of a rotatable rotor, especially a steel rotor, comprising: forming the slot and the surface of the blade so as to have respective parallel surfaces facing one another with the slot surface having a surface component facing relatively inwardly toward the axis of rotation of the rotor, constructing shim means of sintered metal felt, predeforming the shim means beyond a first plastic limit so that the shim means exhibits elastic properties and high strength, and placing the predeformed shim means between the respective parallel surfaces of said slot and blade whereby the shim means effectively elastically absorbs the transfer of centrifugal forces between said rotor and blade during use.

10. A method according to claim 9, wherein the step of predeforming the shim means includes compressing the shim means in a press.

11. A method according to claim 9, wherein the step of predeforming the shim means includes compressing the shim means by placing it into a rotor and blade assembly and rotating said rotor to cause relative movement of said rotor and blade to compress the shim means.

6

12. A method according to claim 9, further comprising the step of fixing said shim means to said rotor.

13. A method according to claim 9, further comprising the step of positioning a predeformed shim means between the radially innermost end of the blade and the bottom of the slot for supporting the blade at rest.

14. A method according to claim 9, wherein said shim means is composed of metal fibers approximately 6 to 15 μm in diameter, and wherein said step of constructing the shim means includes sintering these metal fibers by the application of high heat, pressure and reduced atmosphere which effectively connects the fibers at their contact points.

15. A method according to claim 14, wherein said metal fibers consist of 1.5 percent Co, 22 percent Cr, 9 percent Mo, 0.6 percent W, 18 percent Fe, 0.10 percent C, 1.0 percent Si, 1.0 percent Mn, balance Ni.

16. A method according to claim 9, wherein said shim means is compressed from a thickness of approximately 1.25 mm to approximately 1.00 mm during the predeforming step.

17. A shim for use in turbine rotor blade construction comprising a uniform metallic felt material consisting of sintered metallic fibers, said material having highly elastic properties and providing thermal insulation.

18. A shim according to claim 17, wherein said metallic fibers are approximately 6 to 15 μm in diameter and are sintered by the application of high heat, pressure and reduced atmosphere.

19. A shim according to claim 18, wherein said metallic felt material consists of 1.5 percent Co, 22 percent Cr, 9 percent Mo, 0.6 percent W, 18 percent Fe, 0.10 percent C, 1.0 percent Si, 1.0 percent Mn, and balance Ni.

20. A shim according to claim 17, wherein said metallic felt material is deformed beyond a first plastic limit to achieve the elastic properties.

* * * * *

40

45

50

55

60

65