US 20090095042A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2009/0095042 A1

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(43) Pub. Date: Apr. 16, 2009

(54) **METHOD FOR SURFACE BLASTING CAVITIES, PARTICULARLY CAVITIES IN GAS TURBINES**

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(21) Appl. No.: **11/792,756**

(22) PCT Filed: **Dec. 7, 2005**

(86) PCT No.: **PCT/DE05/02205**

§ 371 (c)(1),
(2), (4) Date: **Jul. 6, 2007**

(30) **Foreign Application Priority Data**

Dec. 10, 2004 (DE) 10 2004 059 592.5

Publication Classification

(51) **Int. Cl.**
C21D 7/06 (2006.01)

(52) **U.S. Cl.** **72/53**

(57) **ABSTRACT**

The invention relates to a method for the surface blasting of hollow spaces or cavities, especially of cavities of gas turbines. According to the invention, shot balls are accelerated with the aid of at least one vibrator, whereby the shot balls accelerated in the ultrasonic range are directed onto surfaces of a cavity that is to be blasted. In that regard, the vibrator is preferably positioned with a small spacing distance, preferably with a spacing distance on the order of magnitude of the diameter of the shot balls utilized for the blasting, from the cavity to be blasted.

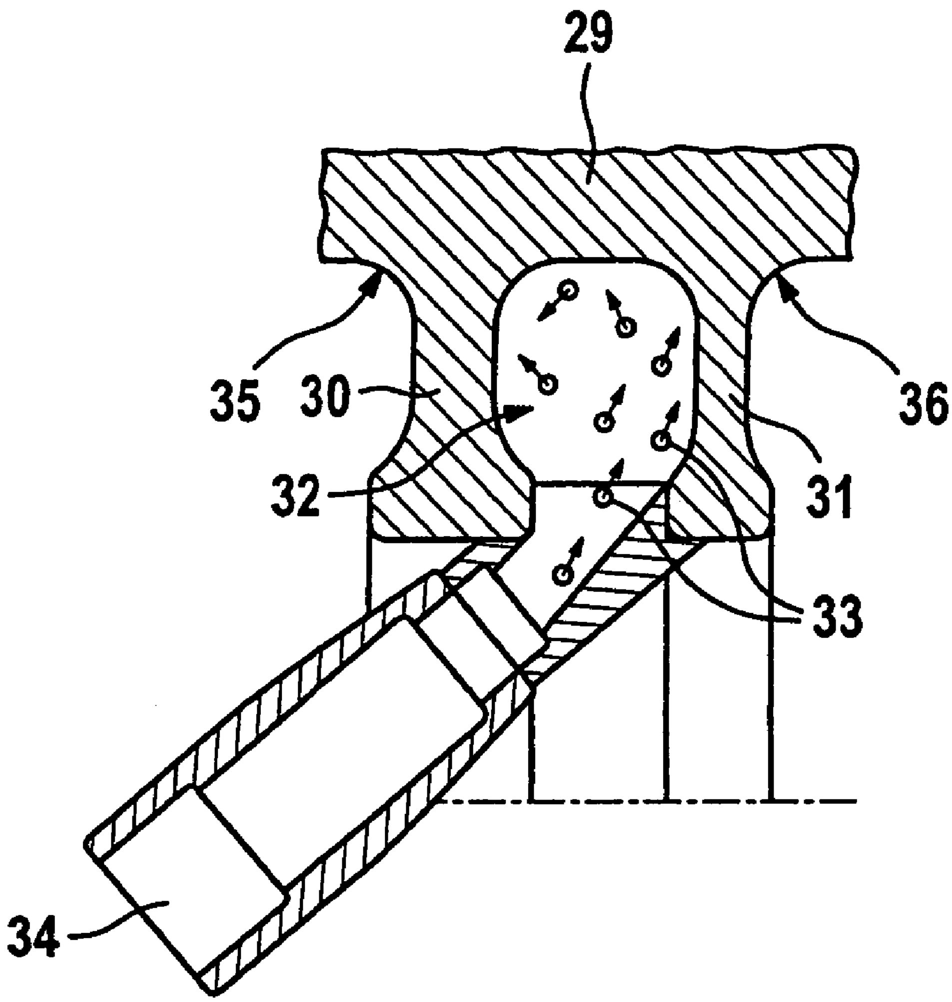


Fig. 1

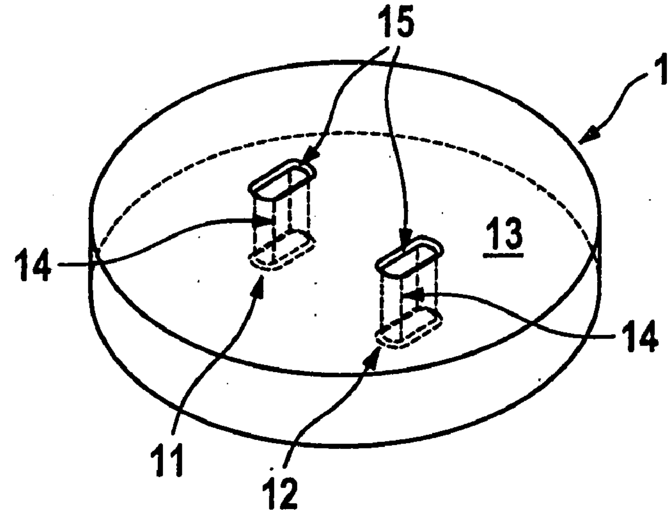


Fig. 2

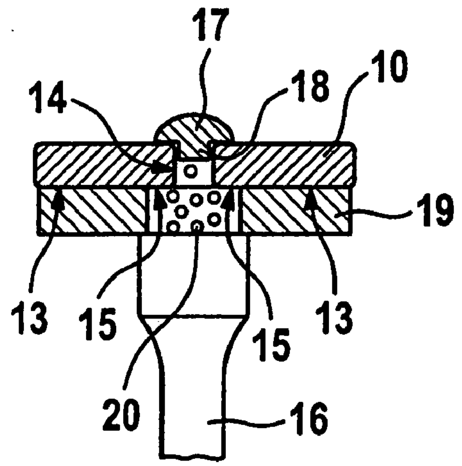
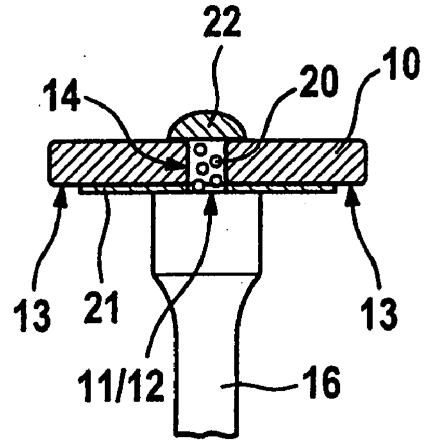


Fig. 3



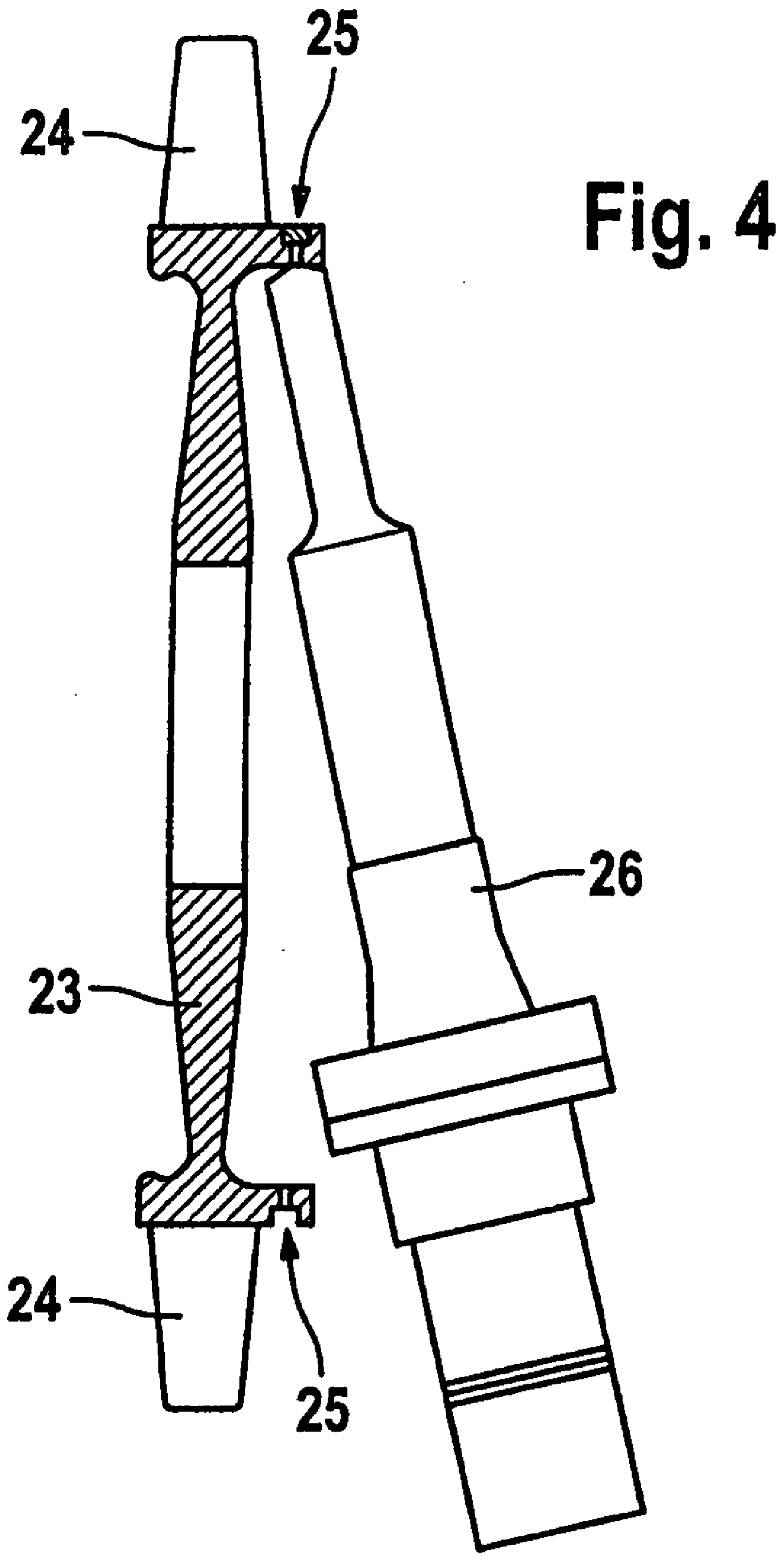

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Fig. 4
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Fig. 5

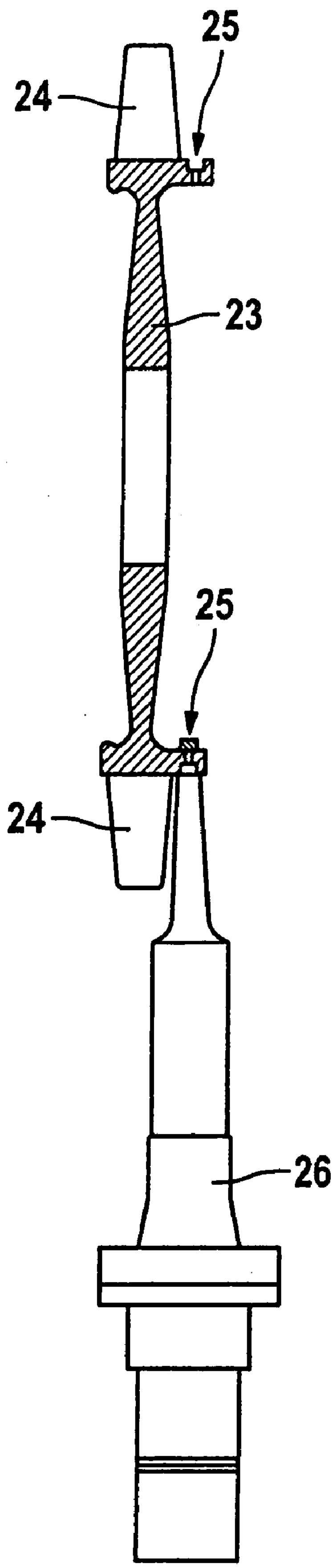
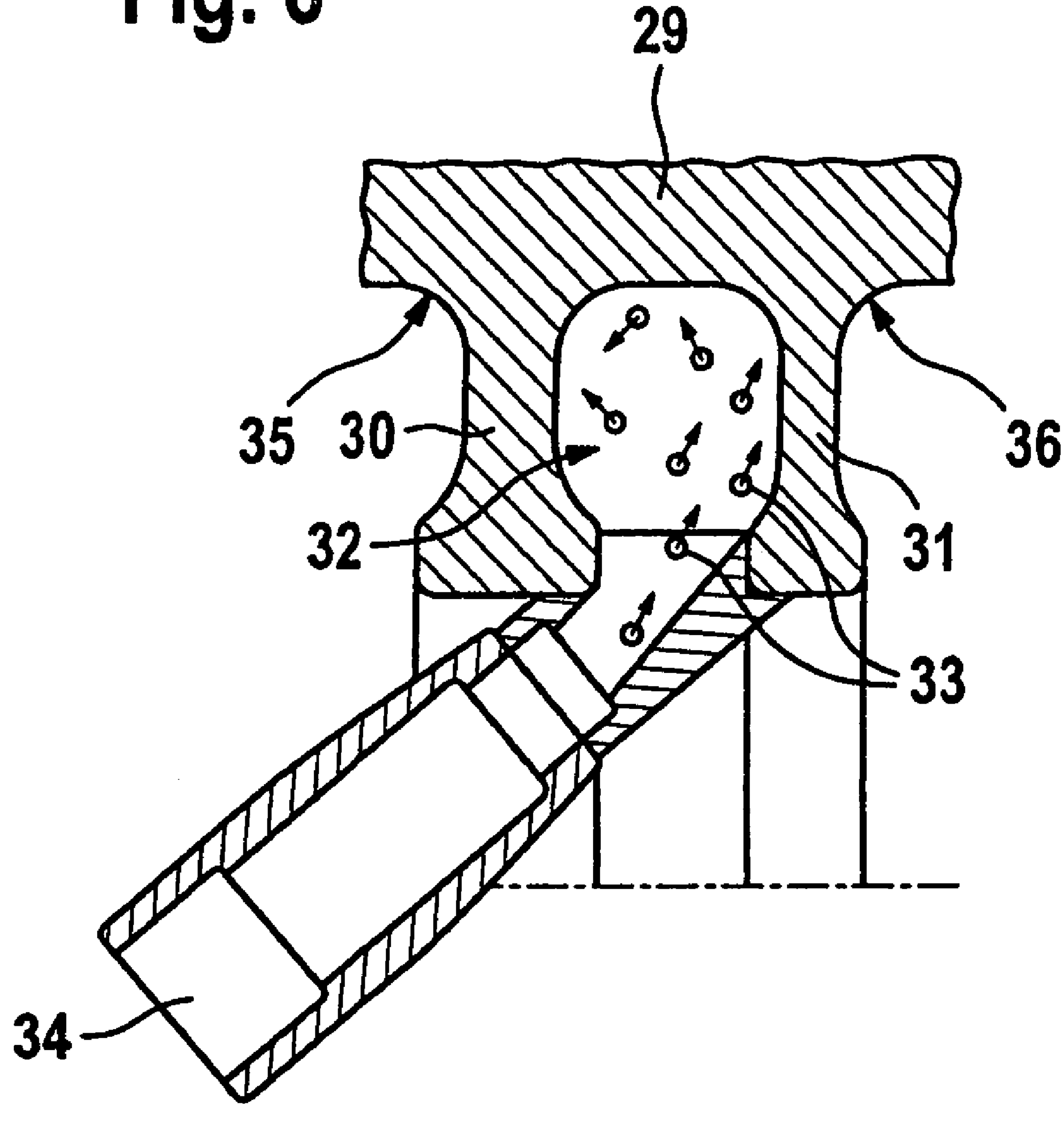


Fig. 6



METHOD FOR SURFACE BLASTING CAVITIES, PARTICULARLY CAVITIES IN GAS TURBINES

[0001] The invention relates to a method for the surface blasting of hollow spaces or cavities, especially cavities of gas turbines.

[0002] Gas turbines, especially aircraft engines, have at least one rotor equipped with rotating runner or rotor blades especially in the area of a compressor as well as a turbine, whereby the rotor blades are increasingly embodied as an integral component of the rotor. Integral bladed rotors are also designated as "blisk" (bladed disk) or "bling" (bladed ring). Generally, through-going bored holes, extending in the radial direction, for fluids, for example oil, are generally integrated in such rotors. Such through-going bored holes are also designated as "bleed holes" and represent hollow spaces or cavities with small cross-sectional areas. Other bored holes extend in the axial direction and often serve for the screwing connection, whereby these bored holes similarly represent highly loaded zones or areas of compressor and turbine. Further cavities with small-cross sectional areas are, for example, located between neighboring rotor disks of a gas turbine rotor. During the operation of a gas turbine, especially the rotors thereof are subject to high demands. In order to reduce the wear rate, the rotors are densified or hardened by special surface treating or processing methods. In that regard, it is of significance to densify or harden also the surfaces of the above described cavities with small cross-sectional areas and the associated transition radii.

[0003] For the hardening of surfaces, the shot peening or shot blasting is usually used according to the state of the art, whereby the shot balls are accelerated with the aid of an airstream or a centrifuge. If, for example, the surfaces of through-going bored holes are to be hardened with the aid of shot balls accelerated by an airstream or a centrifuge, the problem arises, that especially corners or transition areas of the through-going bored holes between a surface of the rotor and an inner surface of the through-going bored holes are subjected to a strong plastic material deformation, whereby the ductility of the material in the area of the through-going bored holes can be reduced and thus disadvantageously influenced. The methods for the surface blasting known from the state of the art are thus suitable only with great limitations for the treatment of cavities with especially tight cross-sectional areas.

[0004] Beginning from this, the problem underlying the present invention is to provide a novel method for the surface blasting of cavities, especially cavities of gas turbines.

[0005] This problem is solved by a method in the sense of patent claim **1**. According to the invention, shot balls are accelerated with the aid of at least one vibrator, whereby the accelerated shot balls are directed onto surfaces of a cavity that is to be blasted and the corresponding transition radii. In that regard, the vibrator is preferably positioned at a small spacing distance, preferably a spacing distance on the order of magnitude of the diameter of the shot balls used for the blasting, away from the cavity that is to be blasted.

[0006] Through the inventive acceleration of the shot balls used for the blasting with the aid of a vibrator, a random motion direction of the shot balls arises due to multiple reflections, whereby material deformations in the area of the cavities are minimized. Furthermore, a temporally smaller impulse or momentum density arises due to the smaller number of the utilized shot balls, whereby similarly the danger of material damages is reduced. In order to provide a momentum sufficient for the surface hardening despite the reduced temporal momentum density, shot balls with an adapted diameter, a higher density and therewith ultimately a greater mass are used.

[0007] According to a preferred further development of the invention, the or each ultrasonic vibrator is operated or driven with a frequency between 10 kHz and 50 kHz, especially with a frequency between 20 kHz and 40 kHz, whereby preferably shot balls with high density and hardness of a ceramic material, especially of tungsten carbide, are used for the blasting.

[0008] Preferably, the method is utilized in the blasting of through-going bored holes extending in the radial direction of a gas turbine rotor or of connecting bored holes extending in the axial direction with a relatively small cross-sectional area of especially 5 mm^2 to 100 mm^2, whereby such a through-going bored hole is first blasted in a transition area between a component surface and an inner surface of the through-going bored hole, and is then blasted in the area of the inner surface, whereby shot balls with a diameter between 0.2 mm and 5 mm, especially between 0.4 mm and 1 mm, are used for the blasting, and whereby the vibrator is operated or driven with a frequency between 10 kHz and 50 kHz, especially at 20 kHz, for the blasting of a radially outward lying transition area between the component surface and the inner surface of the through-going bored hole as well as for the blasting of the inner surface, whereas however the ultrasonic vibrator is operated or driven with a frequency between 10 kHz and 50 kHz, especially at 40 kHz, for the blasting of a radially inward lying transition area between the component surface and the inner surface.

[0009] Preferred further developments of the invention arise from the dependent claims and the following description. Example embodiments of the invention will be explained more closely in connection with the drawing, without being limited hereto. Thereby:

[0010] FIG. **1** shows a strongly schematized illustration of a component with two through-going bored holes to be blasted;

[0011] FIG. **2** shows the blasting of a corner area or transition area between a component surface and an inner surface of the through-going bored hole of the component of the FIG. **1**;

[0012] FIG. **3** shows the blasting of the inner surface of the through-going bored hole of the component of the FIG. **1**;

[0013] FIG. **4** shows a strongly schematized illustration of an integral bladed gas turbine rotor during the blasting, from radially inside, of a through-going bored hole extending in the radial direction;

[0014] FIG. **5** shows a strongly schematized illustration of an integral bladed gas turbine rotor during the blasting, from radially outside, of a through-going bored hole extending in the radial direction;

[0015] FIG. **6** shows a strongly schematized illustration of a gas turbine rotor during the blasting, from radially inside, of a cavity between two rotor disks.

[0016] In the following, the present invention will be described in greater detail with reference to FIGS. **1** to **6**.

[0017] FIG. **1** shows a disk-shaped embodied component **10** with two through-going bored holes **11** and **12**. The through-going bored holes **11** and **12** are bored holes with a relatively small cross-sectional area, especially with a cross-sectional area of 5 mm^2 to 100 mm^2. In the example embodiment of the FIG. **1**, one shall begin from the point that the through-going bored holes **11**, **12** comprise an oval cross-sectional area with a length of 3.8 mm and a width of 1.2 mm. Already from this it follows that the dimensions of the through-going bored holes **11**, **12** are very small.

[0018] With the present invention, a method is now proposed, to densify or harden especially hollow spaces or cavities with such small dimensions, on their surfaces, by shot blasting. For this purpose, in the sense of the present invention, the shot balls are accelerated with the aid of at least one ultrasonic vibrator, especially with the aid of a so-called ultrasonic sonotrode whereby the thusly accelerated shot balls are then directed onto the surfaces of the cavity to be blasted.

[0019] In the sense of the present invention, in that regard, the or each ultrasonic vibrator is operated or driven with a frequency between 10 kHz and 50 kHz, especially with a frequency between 20 kHz and 40 kHz. Preferably shot balls of a ceramic material, preferably of tungsten carbide, are utilized for the blasting. Shot balls of a steel alloy, preferably of a 100Cr6 material, can also be utilized. The shot balls used for the blasting preferably have a polished surface and a diameter that is matched or adapted to the dimensions of the cavity to be blasted.

[0020] Preferably shot balls with a diameter between 0.2 mm and 5 mm, especially between 0.4 mm and 1 mm, are used for the blasting of the through-going bored holes **11**, **12** with small cross-sectional areas as described with reference to FIG. **1**.

[0021] One preferably proceeds in a two-staged manner for the blasting of the through-going bored holes **11**, **12** of the component **10** according to FIG. **1**. In a first stage, corner areas or transition areas between a surface **13** of the component **10** and an inner surface **14** of the through-going bored holes **11** or **12** are blasted. The corner areas or transition areas are identified in FIG. **1** by the reference number **15** and form, in the illustrated example embodiment, a radii-shaped transition between the surface **13** of the component **10** and the inner surface **14** of the respective bored hole **11** or **12**. Following the blasting of the transition areas **15**, then the blasting of the inner surfaces **14** of the through-going bored holes **11** and **12** occurs.

[0022] For the blasting of the corner areas or the transition areas **15** between the surface **13** of the component **10** and the inner surface **14** of the through-going bored holes **11** or **12**, one proceeds as shown in FIG. **2**. An ultrasonic vibrator, namely an ultrasonic sonotrode **16**, is arranged for this purpose in the area of a surface **13** of the component **10** with a small spacing distance relative to the through-going bored hole **11** or **12** that is to be blasted. On the opposite surface **13**, the through-going bored hole **11** or **12** is closed with a closure plug **17**. The closure plug **17** can reach into the through-going bored hole **11** or **12** with a projection **18** according to FIG. **2**. The areas of the surface **13**, which do not belong to the transition area **15** of the through-going bored holes **11** or **12** that is to be blasted, are covered with the aid of a cover **19**, whereby the cover **19** simultaneously can form a spacer or spacing member for maintaining the spacing distance between the sonotrode **16** and the component **10**. In the example embodiment of the FIG. **2**, the spacing distance between the sonotrode **16** and the surface **13** of the component **10** during the blasting of the transition areas **15** lies in the range of a few millimeters, preferably in the range of the five-fold to fifty-fold diameter of the shot balls **20** used for the blasting. Preferably, shot balls **20** with a diameter between 0.4 mm and 1 mm are used for the blasting of such through-going bored holes.

[0023] For the blasting of the inner surfaces **14** of the through-going bored holes **11** and **12**, one proceeds as shown in FIG. **3**. For this purpose, once again, a sonotrode **16** is positioned with a small spacing distance relative to the surface **13** of the component **10**, whereby the entire surface **13** and therewith also the transition area **15** that was previously blasted in the sense of FIG. **2** are covered by a cover **21**. The cover **21** moreover again forms a spacer or spacing member for maintaining a defined spacing distance between the sonotrode **16** and the component **10**. For the blasting of the inner surface **14** of the through-going bored holes **11** and **12**, a smaller spacing distance is maintained between the sonotrode **16** and the surface **13** of the component **10**, as can be seen from a comparison of the FIGS. **2** and **3**. In connection with the blasting of the inner surfaces **14**, this spacing distance lies on the order of magnitude of the diameter of the shot balls used for the blasting, especially on the order of magnitude of half the diameter thereof. When using shot balls with a diameter of 0.4 mm to 1 mm this means that the spacing distance between the sonotrode **16** and the cover **21** lies between 0.2 mm and 1 mm during the blasting of the inner surfaces **14**. As can be seen from FIG. **3**, also during the blasting of the inner surfaces **14**, the through-going bored holes **11** or **12**, on the side thereof lying opposite the sonotrode **16**, are closed by a closure plug **22**, whereby the closure plug **22** does not, however, project into the through-going bored hole **11** or **12**.

[0024] FIGS. **4** and **5** show a rotor disk **23** of an integral bladed rotor, whereby the rotor blades of the integral blades rotor **23** are identified with the reference number **24**. As can be seen from FIGS. **4** and **5**, through-going bored holes **25** extending in the radial direction are integrated into the rotor disk **23**, whereby the through-going bored holes serve for the passage of fluids, especially of oil. The through-going bored holes **25** can be compared with the through-going bored holes **11** or **12** according to FIG. **1** with regard to their geometrical dimensions, so that one may in principle proceed as described in connection with FIGS. **1** to **3** for the blasting of the through-going bored holes **25**, which extend in the radial direction, of the rotor disk **23**.

[0025] FIG. **4** shows the blasting, from radially inside, of the through-going bored holes **25**, which extend in the radial direction, of the rotor disk **23**, FIG. **5** shows the blasting of the same from radially outside. In the blasting of such through-going bored holes **25** on rotor disks **23**, one proceeds in the sense of the present invention, so that an ultrasonic vibrator, namely an ultrasonic sonotrode **26**, is operated or driven with a frequency from 10 kHz to 50 kHz, especially at 20 kHz, for the blasting of the radially outwardly lying corner areas or transition areas between a radially outwardly lying surface of the rotor disk **23** and an inner surface of the through-going bored holes **25** as well as for the blasting of the inner surfaces of the through-going bored holes **25**. On the other hand, for the blasting of a radially inwardly lying corner area or transition area between a radially inwardly lying surface of the rotor disk **23** and the inner surface of the through-going bored holes **25** extending in the radial direction, the ultrasonic sonotrode **26** is operated or driven with a frequency of 10 kHz to 50 kHz, especially at 40 kHz.

[0026] The number of the shot balls used for the blasting and the time duration of the ultrasonic shot blasting are determined dependent on the desired internal residual stress profile to be achieved and the size of the cavity to be blasted.

[0027] The inventive method for the surface blasting of cavities is suitable not only for the blasting of cavities embodied as through-going bored holes or connecting bored holes, but rather also for the blasting of cavities between neighboring rotor disks of a gas turbine rotor. Thus FIG. **6** shows a cut-out section of a gas turbine rotor **29** which comprises two neighboring rotor disks **30** as well as **31**. In the sense of the present invention, a hollow space or cavity **32** between the two neighboring rotor disks **30** as well as **31** can also be densified or hardened with the aid of shot balls **33**, which are accelerated by an ultrasonic vibrator, namely, an ultrasonic sonotrode **34**. For the blasting of the cavity **32** between the two rotor disks **30** and **31** as shown in FIG. **6**, once again preferably shot balls of tungsten carbide or a 100Cr6 material are used, which comprise a larger diameter in distinction to the surface blasting of through-going bored holes. Thus, preferably shot balls with a diameter of 0.5 mm to 6 mm, preferably 2 mm, are used for the surface blasting of the cavity **32**. A bounded or limited blasting cavity can be formed by two separating disks that are to be introduced into the cavity to be blasted, wherein the ultrasonic sonotrode forms the deepest point in the limited blasting cavity. It is pointed out that not only the cavity between the two rotor disks **30** and **31**, as described above, can be blasted, but rather also the side flanks **35** or **36** of the rotor disk **30** or **31**.

[0028] In the sense of the present invention, an ultrasonic shot blasting process is proposed for the surface densification or hardening of cavities, whereby the shot balls are accelerated with the aid of an ultrasonic vibrator, namely with the aid of an ultrasonic sonotrode. The diameter of the shot balls is matched or adapted to the cavity to be treated, whereby preferably shot balls of tungsten carbide are utilized. The shot balls have a polished surface.

[0029] Because smaller velocities of the shot balls occur and moreover a randomly distributed motion direction of the shot balls arises with the ultrasonic shot blasting, therefore the risk of plastic deformations in the area of the blasted cavities, especially on the edges, is minimized. Hereby it is avoided that the ductility of the material, of which the component to be hardened is formed, becomes unacceptably reduced.

1. Method for the surface blasting of cavities of a component, especially of cavities of a gas turbine, whereby shot balls are accelerated with the aid of at least one vibrator, especially with the aid of at least one ultrasonic sonotrode, and whereby accelerated shot balls are directed onto surfaces of a cavity to be blasted and the corresponding transition radii.

2. Method according to claim **1**, characterized in that the or each vibrator is driven with a frequency between 10 kHz and 50 kHz, especially with a frequency between 20 kHz and 40 kHz.

3-16. (canceled)

17. Method according to claim **1**, characterized in that shot balls of a ceramic material, preferably of tungsten carbide, are utilized.

18. Method according to claim **1**, characterized in that metallic shot balls of a steel alloy, preferably of a 100Cr6 material, are utilized.

19. Method according to claim **1**, characterized in that shot balls with a polished surface are utilized, of which the diameter is adapted to the dimensions of the cavity to be blasted.

20. Method according to claim **1**, characterized in that the vibrator, especially the ultrasonic sonotrode, is positioned with a small spacing distance, preferably with a spacing distance in the millimeter range, from the cavity to be blasted.

21. Method according to claim **20**, characterized in that the spacing distance between the ultrasonic vibrator, especially the ultrasonic sonotrode, and the cavity to be blasted lies on the order of magnitude of the diameter, especially the half diameter, of the shot balls utilized for the blasting.

22. Method according to claim **1**, characterized in that through-going bored holes or connecting bored holes with a relatively small cross-sectional area, especially with cross-sectional areas of 5 mm^2 to 100 mm^2, are blasted as the cavities.

23. Method according to claim **22**, characterized in that a through-going bored hole or connecting bored hole are blasted first in a transition area between a component surface and an inner surface of the bored hole and then in the area of the inner surface.

24. Method according to claim **22**, characterized in that shot balls with a diameter between 0.2 mm and 5 mm, especially between 0.4 mm and 1 mm, are utilized for the blasting of the through-going bored holes or connecting bored holes.

25. Method according to claim **22**, characterized in that the ultrasonic vibrator is driven with a frequency of 10 kHz to 50 kHz, especially at 20 kHz, for the blasting of a radially outwardly lying transition area between the component surface and the inner surface of a through-going bored hole extending in the radial direction, as well as for the blasting of the inner surface, whereas the ultrasonic vibrator is driven with a frequency of 10 kHz to 50 kHz, especially at 40 kHz, for the blasting of a radially inwardly lying transition area between the component surface and the inner surface.

26. Method according to claim **1**, characterized in that through-going bored holes extending in the radial direction of a gas turbine rotor, especially an integral bladed gas turbine rotor, or connecting bored holes extending in the axial direction, are blasted as the cavities.

27. Method according to claim **26**, characterized in that a through-going bored hole or connecting bored hole are blasted first in a transition area between a component surface and an inner surface of the bored hole and then in the area of the inner surface.

28. Method according to claim **26**, characterized in that shot balls with a diameter between 0.2 mm and 5 mm, especially between 0.4 mm and 1 mm, are utilized for the blasting of the through-going bored holes or connecting bored holes.

29. Method according to claim **26**, characterized in that the ultrasonic vibrator is driven with a frequency of 10 kHz to 50 kHz, especially at 20 kHz, for the blasting of a radially outwardly lying transition area between the component surface and the inner surface of a through-going bored hole extending in the radial direction, as well as for the blasting of the inner surface, whereas the ultrasonic vibrator is driven with a frequency of 10 kHz to 50 kHz, especially at 40 kHz, for the blasting of a radially inwardly lying transition area between the component surface and the inner surface.

30. Method according to claim **1**, characterized in that radial inwardly lying cavities between neighboring rotor disks of a gas turbine rotor, especially an integral bladed gas turbine rotor, are blasted.

31. Method according to claim **30**, characterized in that shot balls with a diameter between 0.5 mm and 6 mm, especially 2 mm, are utilized for this.

32. Method according to claim **1**, characterized in that a side flank of a rotor disk of a gas turbine rotor, especially an integral bladed gas turbine rotor, is blasted.

33. Method according to claim **32**, characterized in that shot balls with a diameter between 0.5 mm and 6 mm, especially 2 mm, are utilized for this.

34. Method according to claim **1**, characterized in that the time duration of the ultrasonic shot ball blasting and the amplitude to be used, with which the ultrasonic sonotrode is excited, are determined dependent on the number of the shot balls utilized for the blasting and the size of the cavity to be blasted.

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