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METHOD AND INSTALLATION FOR THE ULTRASONIC PEENING OF
THE ANNULAR RECESSES THAT ATTACH BLADES TO A ROTOR

The invention relates to a method of surface treating and compressively prestressing by peening the wall of at least one annular recess approximately in the shape of a dovetail, formed at the periphery of a rotor rim, said annular recess opening to the outside via an annular lateral mouth and having at least two recess ends opening into, respectively, at least one blade introduction opening.

10 In particular, it is necessary to compressively prestress the wall of an annular recess for hammered attachment of the blades to a turbomachine rotor capable of containing blade roots, the lines of contact between the annular recess and each blade root are
15 highly stressed. What happens in operation is that the turbine or fan blades immobilized in an annular recess by various means, are subjected to considerable centrifugal forces leading to significant frictional wear at these lines of contact. This frictional wear
20 reduces the life of the parts in operation and leads to them having to be changed regularly.

In order to improve the fatigue strength of the turbine rotor and to harden the surface of the annular recesses
25 in the region of the lines of contact, it is known practice for the annular recesses to be peened using beads ejected from a compressed air nozzle introduced into each recess. The beads cause permanent compression of the treated surface over a shallow thickness so as
30 to oppose the onset and propagation of cracks at the surface of the part.

These nozzles are able to project only microbeads of a diameter smaller than 1 mm, and typically of between
35 0.3 mm and 0.5 mm. Furthermore, the distribution of the beads, both in terms of position and in terms of speed, is according to a Gaussian distribution.

This method is necessarily lengthy because the entire surface area of the cavity is treated only by a succession of local treatments which may, furthermore, introduce unwanted local deformation and cause the
5 incrustation of bead residue.

In addition, the peening performed is light in order not to generate excessive roughness in the region of the treated zone, and this leads to a limited hardening
10 of the surface. The problem is that since the diameter of the projected beads is small, the more intense the peening, the greater the damage caused to the surface finish.

15 Finally, the method which involves numerous parameters is difficult to control and difficult to reproduce.

The object of the invention is to propose a method for peening the annular recesses of turbine rotors which
20 makes it possible to recreate reproducible prestresses in all the recesses, in a shorter period of time, while at the same time allowing more intense peening, that is to say a greater depth of compression at the surface without, however, introduction of deformation and while
25 at the same time limiting the damage caused to the treated surface. The invention achieves its objective by the fact that the peening method is the ultrasonic method and comprises the following steps:

- 30 a) a dose of beads of a determined diameter is placed on a vibrating surface of a sonotrode already arranged in an intermediate position in a sleeve surrounding said vibrating surface, said sleeve having opposed closing-off means capable of sliding in the recess,
- 35 b) the introduction opening is placed facing said sonotrode,
- c) said sonotrode and said sleeve are moved approximately vertically and together toward said blade introduction opening to place them in a

- peening position in which the closing-off means face the recess ends that open into said opening,
- d) the rotor rim is turned about its axis of rotation arranged horizontally in such a way as to bring the closing-off means into a first recess end so as to form a closed moving chamber containing the beads, and
- e) the entirety of the wall is ultrasonically peened by generating a mist of beads in the moving chamber using the sonotrode excited by means of producing ultrasonic oscillations and by uniformly turning the rotor rim about its axis of rotation until the second recess is reached.
- The method makes it possible to obtain a uniform distribution of the provision of the beads constituting a mist of beads. As the beads of the mist of beads travel in random directions, they strike the walls of the cavities at varying angles, and this improves the surface finish by comparison with beads projected by a nozzle in one predominant direction.

The method requires only a small quantity of beads. It is therefore possible to use beads which are of high quality in terms of hardness and in terms of geometry, for example steel or ceramic ballbearings, which allows the surface finish to be better preserved.

Advantageously, having positioned the closing-off means in the blade introduction opening, the sonotrode is moved approximately vertically so that the vibrating surface is even with the lateral mouth of the recess.

As the volume in which the mist of beads is distributed is smaller than the volume obtained when the vibrating surface remains outside the mouth, the method requires a shorter peening treatment time.

Advantageously at least three successive peening operations are carried out on the wall by reversing the direction of rotation of the rotor rim each time one of the recess ends is neared.

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Not all of the wall of the annular recess is subjected to the impact of the beads at the same time, and this leads to risks that the cavity, particularly the recess containing the blade root, will become deformed, given
10 the magnitude of the diameter of the rim with respect to its thickness. The fact that the wall is treated in three successive treatments allows rim deformation to be compensated for considerably.

15 Of course, it is also possible to carry out three successive peening operations keeping the same direction of rotation of the rotor rim and halting peening when the closing-off cheeks and the vibrating surface near a first mouth end, then reactivating the
20 mist of beads when the closing-off cheeks and the vibrating surface are out of the introduction opening again introduced into the mouth.

Advantageously a deflector is placed in the chamber.

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The deflector may be of approximately triangular geometry with sides parallel to the divergent wall portions so as to reduce the effect of the peening of the zone situated between said deflector and the bottom
30 of the cavity.

Advantageously, having peened a first recess, the rotor part is rotated about its axis of rotation so as to bring the closing-off means into the blade introduction
35 opening, the sonotrode and the sleeve are moved approximately vertically toward the lowered position, the acoustic assembly comprising the sleeve and the sonotrode are moved approximately horizontally toward the introduction opening of a second annular recess

which is brought up to face the sonotrode, and the sonotrode supporting the dose of beads and the sleeve are positioned once again in their raised peening position to peen said second annular recess.

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At the end of the treatment, the sonotrode is advantageously moved approximately vertically toward a lowered position in the sleeve, in which position the dose of beads can be driven from the vibrating surface toward a reservoir through slots formed in the sleeve after the annular recesses formed on the rotor rim have been peened.

Thus, the dose of beads can easily be recovered so that it can either be reused in a subsequent treatment or be replaced.

Advantageously, use is made of a dose of beads the diameter of which exceeds 0.8 mm.

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The beads used in the method according to the invention have a larger diameter than the diameter of the beads that can be projected by a nozzle, which means that the peening can be more intense while at the same time causing less substantial damage to the surface.

The invention also relates to an installation for implementing the method.

30 According to the invention, this installation comprises:

a sonotrode capable of projecting beads of a determined diameter in a moving chamber delimited by a wall portion of the annular recess, the vibrating surface of said sonotrode arranged near the mouth, and a sleeve surrounding the sonotrode and having closing-off means capable of forming a moving chamber which is sealed with said wall portion and said vibrating surface,

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means of producing ultrasonic oscillations capable of exciting said sonotrode,
first means for moving said sonotrode approximately vertically, and second means for moving said closing-off means approximately vertically,
5 a first clearance smaller than the diameter of the beads being formed between said sonotrode and said sleeve, and
a second clearance smaller than the diameter of the
10 beads being formed between said closing-off means arranged in said annular recess and the annular recess.

The installation may comprise a number of acoustic assemblies each comprising a sonotrode and a sleeve,
15 arranged around the rotor rim, said acoustic assemblies being capable of moving in an axial direction of the rotor rim.

Advantageously, the installation comprises a third
20 clearance smaller than the diameter of the beads formed between said vibrating surface arranged in said mouth and the mouth.

The installation advantageously comprises a fourth
25 clearance smaller than the diameter of the beads formed between an end of the sleeve and the mouth which when the vibrating surface is not closing off the mouth, ensures the chamber is sealed correctly.

30 The various elements of the installation are arranged in such a way that no bead can jam said elements capable of moving. Furthermore, the sonotrode and the sleeve comprising the closing-off means have a geometry tailored to the shape of the cavity to be treated. In
35 particular, the vibrating surface is of a shape that complements the mouth and the closing-off means are formed in such a way as to seal the chamber correctly.

Advantageously, the second movement means are capable of moving the closing-off means and the sonotrode at the same time.

- 5 The first movement means and the second movement means can advantageously be operated simultaneously.

At the beginning of the treatment, the sleeve and the sonotrode are placed in an intermediate position in
10 which the space generated by the closing-off means of said sleeve and the vibrating surface of said sonotrode constitutes a reservoir for the dose of beads. Next, said sleeve and said sonotrode supporting the dose of beads are moved jointly with the same movement.
15 Finally, the sonotrode and/or the closing-off means can be moved individually, depending on the geometry of the cavity to be treated, until, respectively, the vibrating surface closes off the mouth of the cavity and the closing-off means close off the openings of the
20 cavity.

Advantageously, the installation comprises support means for supporting the rotor rim that is to be treated and means of driving said support means to
25 cause the annular recess to rotate uniformly.

The installation advantageously comprises means for driving the dose of beads from the vibrating surface toward a reservoir.

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These simple means make it possible to drive the dose of beads during a treatment if necessary, or at the end thereof, either to refresh the beads or to replace them.

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Advantageously, the installation comprises means for moving the sonotrode and the sleeve approximately horizontally.

The number of annular recesses, arranged indifferently on a rotor rim and having the same cross section may thus be treated with one and the same installation but is moved in such a way as to position the sonotrode and
5 the sleeve to face the recess in question.

Further features and advantages of the invention will become apparent from reading the following description given by way of non-limiting example and made with
10 reference to the appended drawings in which:

- figure 1 is a front view of a rotor rim,
- figure 2 is a front view of a fan blade arranged in an annular cavity formed at the periphery of the
15 rotor rim,
- figure 3 is a view of the installation, the sleeve and the sonotrode being placed in the intermediate position,
- figure 4 is a section through the installation on a
20 mid-plane perpendicular to the axis of rotation of the rotor rim, the sleeve and the sonotrode being placed in the raised peening position,
- figure 5 is a section of figure 4 on V-V,
- figure 6 is a section through the sleeve containing
25 the sonotrode, in their intermediate position, and
- figure 7 is a section through the sleeve containing the sonotrode in its lowered position.

Figure 1 shows a rotor rim 1 comprising three annular
30 recesses 2 formed at the periphery of the rotor rim 1 and distributed over different diameters of said rotor rim 1. These annular recesses 2 are approximately in the shape of dovetails and have a mouth 2A of approximately annular shape.

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In order to allow the fitting of the roots 4, approximately in the shape of dovetails, of the fan blades 6 in the recess 2, said recess 2 has a blade introduction opening 5 visible in figure 3.

Each blade root 4 is mounted in turn by sliding in the introduction opening 5. One or more blade fixing devices (not depicted) allow the blade 6 to be immobilized.

Figure 2 shows that the walls of the recess 2 and the blade root 4 rest on one another along two lines of contact 2B.

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The object of the invention is to propose a method and an installation for compressively prestressing the wall 2C of each recess 2 and, in particular, the regions of the two lines of contact 2B, so as to increase the resistance to wear of these lines of contact 2B, the wear being brought about by friction between the blade root 4 and the wall of the recess 2, and thus improve the fatigue strength of the rotor rim 1.

20 Figure 3 shows an example of an installation used for implementing the method and in which just one acoustic assembly is used, said acoustic assembly, positioned below the rotor rim 1, being able to be moved vertically and horizontally.

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The rotor rim 1 is held by a chuck 7 which can drive said rotor rim 1 in rotation about its axis of rotation 1A, arranged horizontally.

30 A sonotrode 8, the vibrating surface 8A of which is placed in an intermediate position in a sleeve 16, is mounted so that it can move under the rotor rim 1. A dose of beads is placed about the vibrating surface 8A. The acoustic assembly comprising the sonotrode 8 and the sleeve 16 is moved horizontally until the vibrating surface 8A of the sonotrode 8 is facing the recess 2 to be treated.

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The rotor rim 1 is turned about its axis 1A so as to place the introduction opening 5 facing the vibrating surface 8A.

5 Next, the sonotrode 8 and the sleeve 16 are moved vertically toward their raised peening position and the rotor rim is turned to bring the vibrating surface 8A near to a first recess end 5A for example so that the closing-off cheeks 14A and 14B formed on the sleeve 16
10 position themselves in the recess 2 in such a way as to form a closed moving chamber 12.

As indicated in figure 4, said moving chamber 12 is delimited by the wall portion 2'C, the vibrating
15 surface 8A which closes off the mouth portion 2A, the closing-off cheeks 14A and 14B and the sleeve 16.

The separation L1 between the two closing-off cheeks 14A and 14B is approximately equal to the
20 circumferential extent L2 of the introduction opening 5.

Beads 10 of a diameter of between 0.8 mm and 5 mm, preferably equal to 1 mm, are projected by the
25 vibrating surface 8A, oriented upward, of the sonotrode 8, into the chamber 12.

Figure 5 shows that the vibrating surface 8A is excited by a vibration generator 18, for example a quartz
30 generator, so as to create a mist of beads 10 in a chamber 12. A deflector 15 which is borne by the closing-off cheeks 14A and 14B may be placed in the mist of beads 10 so as to lessen the effect of the peening of the bottom of the recess and increase the
35 peening of the internal flanks of the mouth 21. Said deflector 15 is triangular with sides approximately parallel to the wall portions 2'C and to the bottom of the recess.

The clearance e1 formed between the sonotrode 8 and the sleeve 16 is smaller than the diameter of the beads 10, which means that no bead 10 can slip between the vibrating surface 8A and said sleeve 16.

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The closing-off cheeks 14A and 14B in the shape of dovetails have axial cross sections that more or less complement those of the recess 2, so that in the raised peening position, the clearance e2 formed between each
10 closing-off cheek 14A, 14B and the wall portion 2'C that is to be peened is smaller than the diameter of the beads 10. Thus, no bead 10 can escape from the chamber 12.

15 Likewise, when the vibrating surface 8A closes off the mouth 2A in the raised peening position, a third clearance e3, formed between the vibrating surface 8A of the sonotrode 8 and the mouth 2A is smaller than the diameter of the beads 10 so that no bead 10 can leave
20 the chamber 12. If the vibrating surface 8A does not close off the mouth, a fourth clearance e4 lying between an end 16A of the sleeve 16 and the mouth 2A ensures that the chamber 12 is sealed.

25 A first slide 20 allows the sonotrode 8 to be moved vertically by causing said sonotrode 8 to slide in the sleeve 16. A second slide 22, borne by a support structure 24, itself allows the sonotrode 8 and the sleeve 16 both to move vertically. Operating means (not
30 depicted) allow said first slide 20 and said second slide 22 to be operated. Means (not depicted), for example rails, allow the acoustic assembly comprising the sonotrode 8 and the sleeve 16 to be moved horizontally, so as to position it facing a recess that
35 is to be treated.

The first slide 20 may be borne either by the second slide 22, as shown in figure 5, or by the support structure 24, in which case the two slides 20 and 22

need to be operated synchronously in order to raise the sonotrode 8 and the sleeve 16 together toward the raised peening position.

5 Before beginning the operation of treating an axial recess 2, the sonotrode 8 is placed in an intermediate position in the sleeve 16, in which position the space delimited by the sleeve 16 and the vibrating surface 8A constitutes a receptacle 26 able to contain the dose of
10 beads 10 deposited on the vibrating surface 8A, as depicted in figure 6.

Having fixed the rotor rim 1 by holding means comprising the chuck 7, the sonotrode 8 and the sleeve
15 16 are moved close to a first recess 2 to be treated, and the introduction opening 5 of said first recess 2 is brought to face the sonotrode 8 by rotating the rotor rim 1 about its axis of rotation 1A using drive means (not depicted). The drive means for example
20 comprise a motor.

The sonotrode 8 and the sleeve 16 are moved toward their raised peening position by simultaneously, using the slide 22, moving the closing-off cheeks 14A and 14B
25 and the vibrating surface 8A into the introduction opening 5, then the rotor rim 1 is turned until the two cheeks 14A and 14B are in the end 5A for example. From that moment, peening of the wall portion 2'C of the first recess 2 can be performed by actuating the
30 vibration generator 18 which generates a mist of beads 10 in the sealed moving chamber 12 and the rotor rim 1 is turned uniformly about its axis of rotation 1A so as to peen the entirety of the wall 2C.

35 When the first cheek 14A nears the end 5B of the mouth 2A, the direction of rotation of the rotor rim 1 is reversed and the wall portion 2'C continues to be peened as far as the other end 5A of the mouth 2A. The process is repeated once more until the end 5B is

reached again. Of course, the method may involve more than three peening passes like the aforementioned.

As soon as the peening of the first recess 2 is over,
5 the rotor rim 1 is turned so that the closing-off cheeks 14A, 14B position themselves in a blade introduction opening 5, the sonotrode 8 and the closing-off cheeks 14A and 14B are extricated from the introduction opening 5, then the acoustic assembly
10 comprising the sonotrode 8 and the sleeve are moved horizontally to face a second recess 2, and treatment is resumed according to the aforementioned method and so on until all of the axial recesses 2 formed on the rotor rim 1 have been treated.

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At the end of the treatment, the sonotrode 8 is withdrawn to its lower position depicted in figure 7, in which the dose of beads 10 is extricated. The beads 10 are, for example, blown from the surface 8A using a
20 fan 28 through slots 30 formed in the sleeve 16 and recovered in a reservoir 32. Said beads 10 can then be refreshed or alternatively replaced with a view to a later treatment.



CLAIMS

1. A method of surface treating and compressively prestressing by peening the wall (2C) of at least one annular recess (2) approximately in the shape of a dovetail, formed at the periphery of a rotor rim (1), said annular recess (2) opening to the outside via an annular lateral mouth (2A) and having at least two recess ends (5A, 5B) opening into, respectively, at least one blade introduction opening (5),
- which method comprises the following steps:
- a) a dose of beads (10) of a determined diameter is placed on a vibrating surface (8A) of a sonotrode (8) already arranged in an intermediate position in a sleeve (16) surrounding said vibrating surface (8A), said sleeve (16) having opposed closing-off means (14A, 14B) capable of sliding in the recess (2),
- b) the introduction (5) opening is placed facing said sonotrode (8),
- c) said sonotrode (8) and said sleeve (16) are moved approximately vertically and together toward said blade introduction opening (5) to place them in a peening position in which the closing-off means (14A, 14B) face the recess ends (5A, 5B) that open into said opening (5),
- d) the rotor rim (1) is turned about its axis of rotation (1A) arranged horizontally in such a way as to bring the closing-off means (14A, 14B) into a first recess end (5A) so as to form a closed moving chamber (12) containing the beads (10), and
- e) the entirety of the wall (2C) is ultrasonically peened by generating a mist of beads (10) in the moving chamber (12) using the sonotrode (8) excited by means (18) of producing ultrasonic oscillations and by uniformly turning the rotor



rim (1) about its axis of rotation (1A) until the second recess is reached.

2. The method as claimed in claim 1, wherein, having moved the sonotrode (8) and the sleeve (16) together into the peening position, the sonotrode (8) is moved approximately vertically so that the vibrating surface (8a) is even with the lateral mouth of the recess (2).
3. The method as claimed in either of claims 1 and 2, wherein at least three successive peening operations are carried out on the wall (2C) by reversing the direction of rotation of the rotor rim (1) each time one of the recess ends is neared.
4. The method as claimed in any of claims 1 to 3, wherein a deflector (15) is placed in the chamber (12).
5. The method as claimed in any of claims 1 to 4, wherein, having peened a first recess, the rotor part (1) is rotated about its axis of rotation so as to bring the closing-off means into the blade introduction opening (5), the sonotrode (8) and the sleeve (16) are moved approximately vertically toward the lowered position, the acoustic assembly comprising the sleeve (16) and the sonotrode (8) are moved approximately horizontally toward the introduction opening (5) of a second annular recess (2) which is brought up to face the sonotrode (8), and the sonotrode (8) supporting the dose of beads (10) and the sleeve (16) are positioned once again in their raised peening position to peen said second annular recess (2).



6. The method as claimed in one of claims 1 to 5, wherein use is made of a dose of beads (10) the diameter of which exceeds 0.8 mm.
- 5 7. An installation for implementing the method as claimed in any of claims 1 to 6, and which comprises:
- 10 a sonotrode (8) capable of projecting beads (10) of a determined diameter in a moving chamber (12) delimited by a wall portion (12'C) of the annular recess (2), the vibrating surface (8A) of said sonotrode (8) arranged near said mouth (2A), and a sleeve (16) surrounding the sonotrode (8) and having closing-off means (14A, 14B) capable of
- 15 forming a moving chamber (12) which is sealed with said wall portion (2'C) and said vibrating surface (8A),
- means (18) of producing ultrasonic oscillations capable of exciting said sonotrode (8),
- 20 first means (20) for moving said sonotrode (8) approximately vertically, and second means (22) for moving said closing-off means (14A, 14B) approximately vertically,
- a first clearance (e1) smaller than the diameter of the beads (10) being formed between said sonotrode (8) and said sleeve (16), and
- 25 a second clearance (e2) smaller than the diameter of the beads (10) being formed between said closing-off means (14A, 14B) arranged in said annular recess (2) and the annular recess (2).
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8. The installation as claimed in claim 7, and which comprises a third clearance (e3) smaller than the diameter of the beads (10) formed between said vibrating surface (8A) arranged in said mouth (2A) and the mouth (2A).
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9. The installation as claimed in either of claims 7 and 8, and which comprises a fourth clearance (e4)



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smaller than the diameter of the beads (10) formed between an end (16A) of the sleeve (16) and the mouth (2A).

- 5 10. The installation as claimed in any of claims 7 to 9, wherein the second movement means (22) are capable of moving the closing-off means (14A, 14B) and the sonotrode (8) at the same time.
- 10 11. The installation as claimed in any of claims 7 to 10, wherein the first movement means (20) and the second movement means (22) can be operated simultaneously.
- 15 12. The installation as claimed in any of claims 7 to 11, and which comprises support means for supporting the rotor rim (1) that is to be treated and means of driving said support means to cause the annular recess (2) to rotate uniformly.
- 20 13. The installation as claimed in any of claims 7 to 12, and which comprises means (28) for driving the dose of beads (10) from the vibrating surface (8A) toward a reservoir (32).
- 25 14. The installation as claimed in any of claims 7 to 13, and which comprises means [lacuna] for moving the sonotrode (8) and the sleeve (16) approximately horizontally.